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The Economic Benefits of Advanced Product Data

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The benefits of computer-aided design (CAD) are widely accepted for new designs. What, however, are the economic benefits of converting drawings to CAD models for military mechanical spare parts procurement and production? Based on our analysis, we estimate that repetitive conversions from raster to vector drawings following the first spares procurement cost the Defense Logistics Agency an extra $48 million over the last 10 years for consumable spare and replacement parts procurements. Had DoD taken delivery of CAD data from the original equipment manufacturer, an additional $35 million potentially could have been avoided. We conducted this analysis in order to assess the opportunity for future cost savings through the acquisition and distribution of CAD data. This analysis also serves as a benchmark to measure the offsetting cost of this opportunity, such as data management and possibly the development and implementation costs associated with neutral CAD formats. (These costs were not examined in this report.)

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Executive Summary

The Department of Defense (DoD), through its Defense Logistics Agency (DLA), procures and distributes 2.7 million hardware items needed to maintain military systems. Of these, 470,000 items are specified by DoD-maintained product data packages. While most of these data originally were produced by private-sector defense manufacturers, DoD has acquired the designs in order to procure spare parts competitively, to maintain defense hardware in the field and in depots, and to modernize weapon systems when a private manufacturer is not available.

Historically, these data have been recorded on paper, then photographed and attached to aperture cards. Since the late 1980s, DoD has embarked on an effort to convert all product data into a standard electronic format. That format, known as C4, is raster—an electronic picture that is neither editable (except pixel-by-pixel) nor machine interpretable. Because of the raster characteristics, spare parts manufacturers taking advantage of computer-aided design (CAD) and manufacturing systems must take the DoD raster data and recreate the design in more advanced formats. While DoD nominally pays for the manufacture of parts, in reality it is paying for data format conversion and engineering validation, as well as manufacturing. DoD takes delivery of the resulting parts but does not take delivery of the advanced data that helped to produce those parts. When, for competitive items, DoD makes future awards to different manufacturers, it pays for the data reengineering again and again.

According to our analysis, repetitive conversions following the first spares procurement have cost DLA an extra $48 million over the last 10 years. If DoD had taken delivery of CAD data from the original equipment manufacturer, an additional $35 million potentially could have been avoided. Eliminating repeated conversions, less any incremental cost of storing and maintaining CAD data, represents an opportunity for DLA to reduce material acquisition costs—a savings that would be passed through to DLA military customers. Additional benefits to lead-time and quality remain to be quantified. Our analysis suggests that data maintenance by DLA can be significantly improved through representation in CAD models, and can lead to significant operational benefits.

We recommend that DLA establish, or procure as services, the systems and procedures to store, maintain, and distribute CAD data. We recommend that DLA then take delivery of CAD data for parts that were modeled at government expense. In addition, DoD weapon acquisition programs should obtain access to CAD data for part designs funded by the government and likely to be competitively procured as spares. DLA should not undertake the wholesale conversion of legacy data. Rather, DLA should take delivery of CAD data as they become available under future procurements when the savings from future procurements are expected to exceed the cost of conversion, storage, and maintenance.

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Acknowledgements

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Chapter 1

Introduction

The benefits of computer-aided design (CAD) are widely accepted for new designs. What, however, are the economic benefits of converting drawings to CAD models for military mechanical spare parts procurement and production?

This report presents our estimate of costs the Department of Defense (DoD) incurred during the last 10 years because paper or raster drawings for consumable spare and replacement parts procurement were distributed rather than CAD or vector data. LMI conducted this analysis for the Defense Logistics Agency (DLA) to assess the opportunity for cost savings through CAD data acquisition and distribution. The analysis also serves as a benchmark to measure the offsetting costs of this opportunity, such as data management and possibly the development and implementation costs associated with neutral CAD formats. Those costs are not examined in this report.

BACKGROUND

The DoD, through DLA, manages approximately 4 million consumable items to support military operations. The military services manage roughly an additional 1 million reparable components and end items. Associated with these 5 million items, DoD owns approximately 107 million sheet images of engineering data.[1] Although most of these data originally were produced by private-sector defense manufacturers, DoD has acquired the designs to procure spare parts competitively, to maintain defense hardware in the field and in depots, and to modernize weapon systems when a private manufacturer is not available.

Historically, these data were recorded on paper, then photographed and attached to aperture cards. Since the late 1980s, DoD has been converting all engineering data, whether from paper or the most advanced software system, into the lowest electronic common denominator—two-dimensional (2-D) raster format,[2] which provides an electronic picture of a blueprint and other technical documents (see Figure 1-1). That picture, however, is neither editable (except pixel by pixel) nor machine interpretable. As a result, manufacturers who take advantage of computer-aided engineering and production systems must use DoD raster data to recreate the design in more advanced formats, such as the three-dimensional (3-D)

[1] Joint Engineering Data Management Information and Control System (JEDMICS) Home Page on the World Wide Web at http://206.3.148.4/gsc/c4spec/C4SPEC03.HTM, 9 December 1999.

[2] DoD defines the requirements for a 2-D raster format known as "C4" in military specification MIL-PRF-28002C, *Raster Graphics Representation in Binary Format, Requirements for.* The C4 format is a tiled, binary bitmap with a resolution of 200 pixels per inch.

CAD model (see Figure 1-2). In these advanced formats, design and specification changes can be made more rapidly, and the data can be directly processed by numerically controlled equipment.

Figure 1-1. Example of Raster Image

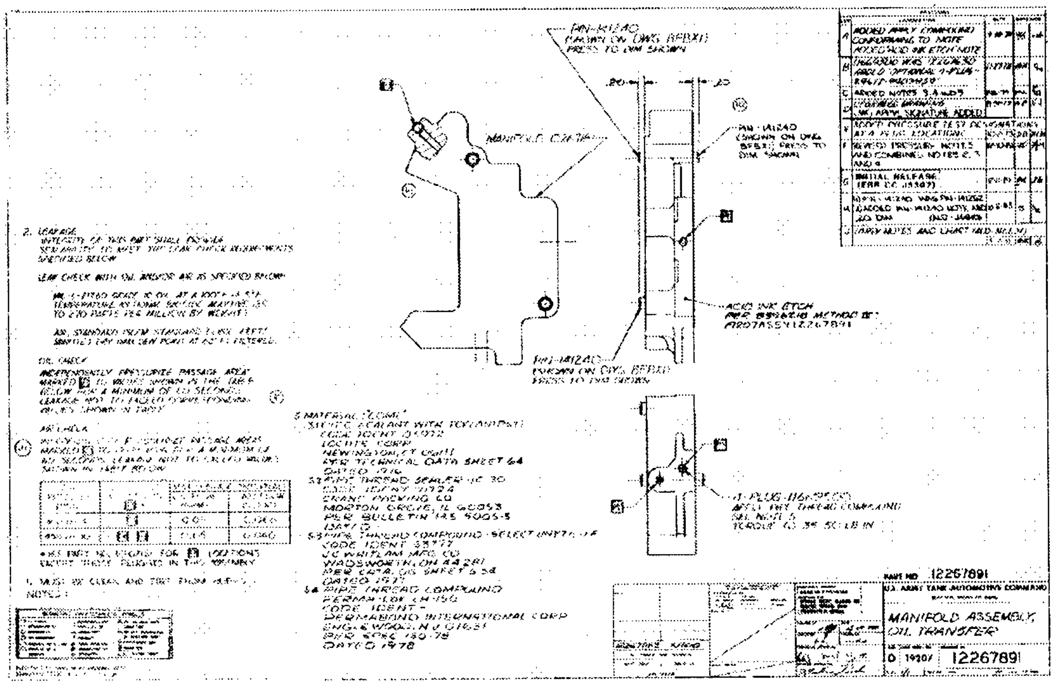
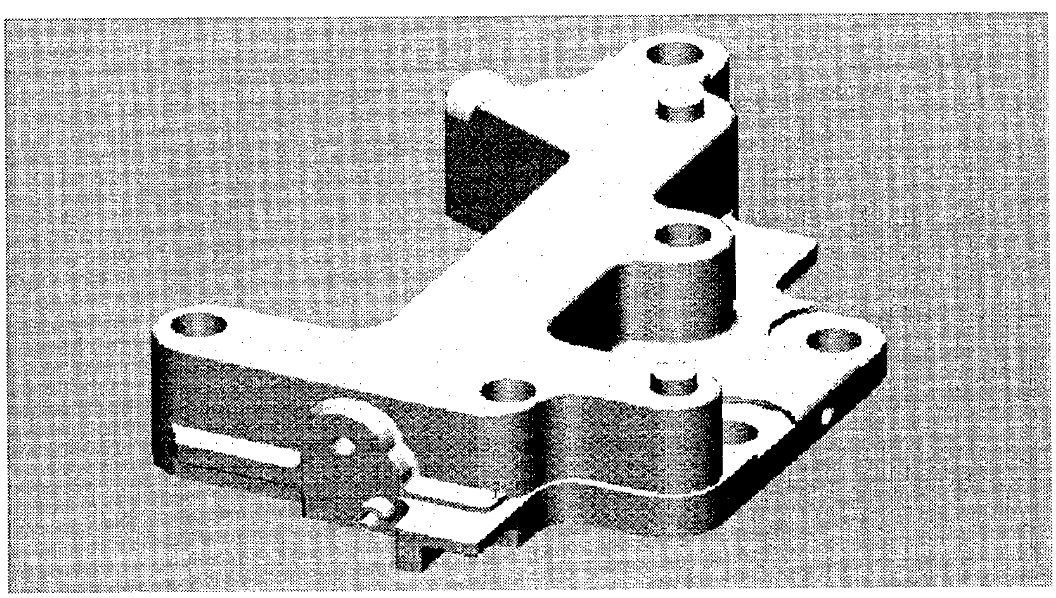


Figure 1-2. Example of 3-D CAD Model of Above Part



While DoD nominally pays for the manufacture of parts, in reality it pays for data format conversion, engineering validation, and manufacturing. DoD takes delivery of the resulting parts but not of the CAD data that helped to produce those parts. When DoD makes awards to different manufacturers for competitive items, it pays again and again for data reengineering.

In our report, we estimate the number of DLA-managed mechanical parts in previous procurements that likely required conversion of raster data into CAD models. We then estimate the DoD-incurred cost for repeated raster-to-vector conversion and validation for each time these parts were procured competitively from a different manufacturer. Our estimate includes the time and cost required to convert to a single proprietary vector format, as well as to two neutral formats, IGES[3] and STEP,[4] which potentially can translate data from any proprietary system to any other system.[5]

APPROACH

The diagram in Figure 1-3 outlines our analysis approach.

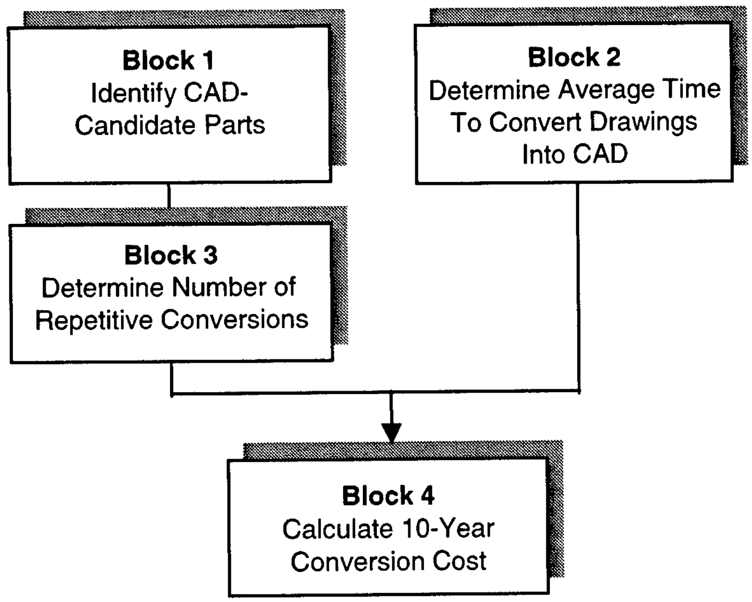
We began by estimating the number of previously procured DLA-managed parts for which manufacturers likely would convert the raster drawings to CAD models (Block 1). We call these "CAD-candidate parts." Simultaneously, we analyzed data captured in pilot projects to quantify the time required to convert paper or raster engineering drawings into CAD files (Block 2). Next, we analyzed the procurement profile of the CAD-candidate parts to determine the number of different suppliers (and therefore repetitive conversions) during the last 10 years (Block 3). Finally, we used the conversion and procurement data to calculate DLA CAD conversion costs during the last 10 years (Block 4).

[3] IGES, formally known as ANSI/US PRO/IPO 100-1996, *Initial Graphics Exchange Specification IGES 5.3*, is supported by many CAD packages. The standard, however, does not provide for complete, accurate product representation.

[4] STEP is a series of international standards known collectively as ISO 10303, *Industrial Automation Systems and Integration—Product Data Representation and Exchange*. ISO 10303-203:1994, *Industrial Automation Systems and Integration—Product Data Representation and Exchange—Part 203: Application protocol: Configuration controlled design* (AP203) defines nominal 3-D geometry for mechanical parts. This standard, however, lacks both tolerances and supporting text information. *Industrial Automation Systems and Integration—Product Data Representation and Exchange—Part 224: Application Protocol: Mechanical Product Definition for Process Planning Using Machining Features* (AP224) addresses these shortfalls, although we know of no CAD vendors that support it yet. The South Carolina Research Authority has developed an AP224 translator for Parametric Technology Corporation's Pro/ENGINEER under the sponsorship of DoD.

[5] For information on product data format alternatives, refer to Logistics Management Institute, *Product Data Strategies for the Department of Defense*, Report DL802T1, Eric L. Gentsch and Richard H. J. Warkentin, August 1998.

Figure 1-3. Approach



SCOPE

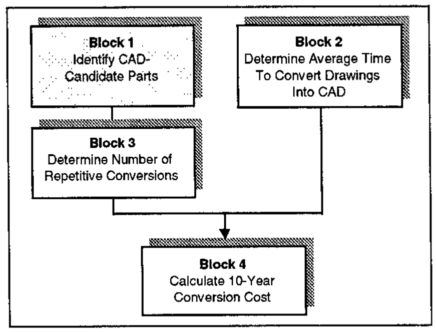
We focused on mechanical and structural items, such as aircraft, automotive, and ship components. We obtained time data for the conversion of mechanical parts to STEP AP203 and AP224 application protocols. The international standards supporting mechanical engineering data are more fully developed than those for other commodities. Our approach also could be applied to other commodities, such as electronics and composite structures.

OVERVIEW OF REPORT STRUCTURE

In this report we present the methodology and findings of our analysis. The report is organized into five chapters with supporting appendixes. We describe our methodology and results in identifying DLA-managed CAD-candidate parts in Chapter 2. In Chapter 3, we analyze raster-to-vector conversion time data. Chapter 4 contains the procurement history and conversion cost analysis for the CAD-candidate parts. In Chapter 5, we list our findings, conclusions, and recommendations.

Chapter 2
CAD-Candidate Parts

Our task required that we estimate DoD's incurred cost of distributing raster rather than vector product data. We identified those DLA-managed parts whose drawings were likely to have been replaced by CAD models in previous procurements. To do so, we used a two-step filtering process. First, from government-maintained databases we derived active, competitively procured, mechanical national stock numbers (NSNs). From these, we drew a random sample. For each sample NSN, we retrieved the associated technical data from JEDMICS[1] repositories for review and to estimate whether the parts were candidates for CAD models. In this chapter, we describe our process and the resulting characterization of the CAD-candidate parts.



THE POPULATION

Using the DLA Item & Header File[2] and the Federal Logistics Information System (FLIS)[3] accessed through the Haystack[4] online database service, we extracted DLA-managed parts likely to require conversion of raster data to aid in the manufacturing process.[5]

First, we searched for mechanical, machined parts that require CAD for process planning and manufacturing. These also were of interest because STEP AP203 and AP224, which are tailored for mechanical parts, are among the most mature of the STEP application protocols. We began with the 2,710,826 NSNs managed by the three DLA hardware supply centers.

[1] DoD stores engineering data on paper, on aperture cards, and in JEDMICS. JEDMICS stores the data on wide-area, network-accessible optical media, providing near-immediate on-line access at distributed workstations. Although JEDMICS is a data repository capable of storing a large number of data formats, the overwhelming majority of data stored in JEDMICS exist in C4 raster format.

[2] The DLA Item & Header File is maintained by the DLA Office of Operations Research and Resource Analysis (DORRA) and is updated quarterly.

[3] FLIS is maintained at the Defense Logistics Information Service (DLIS) in Battle Creek, MI. It is the federal catalog system that contains the technical and catalog data on items managed by the military services, DLA, and the General Services Administration.

[4] Haystack is a service of Information Handling Services, Inc. It uses logistics and procurement data supplied by the U.S. Government.

[5] Appendix A contains expanded details of our filtering process.

Next, we searched for parts that were of a competitive, build-to-print nature, with the potential for procurement from several different manufacturers and not readily available from commercial catalogs. We eliminated NSNs coded by DLA as sole-source or restricted source. This step left 470,577 NSNs. Then, by examining the Federal Supply Class (FSC), we disregarded FSCs likely to contain non-mechanical or commercial items. Where doubt existed, we included FSCs rather than excluded them. Appendix B contains a list of FSCs managed by the three DLA hardware centers, and notes their inclusion in or exclusion from our analysis. Following this step, 219,639 NSNs remained.

A final requirement was that the part had to be active, which we defined as procured within the last 6 years. Without this filter, the subsequent sample would have included a significant number of items with no government-maintained procurement data. An earlier LMI study reported that only 21 percent of DLA-managed hardware items were procured within the previous 5 years and 36 percent had no procurement history.[6] As expected, this step eliminated many NSNs, leaving 74,139 NSNs as candidates.

With these filters, we narrowed the nearly 3 million DLA hardware items to approximately 74,000 parts for which manufacturers may have created CAD models from raster images. Table 2-1 is a summary of the filtering results by supply center.

Table 2-1. CAD-Candidate Filtering Results

Defense Supply Center source of supply code	Columbus (non-electronics only) (S9C)	Richmond (S9G)	Philadelphia (industrial items only) (S9I)	Total NSNs
Number of parts matching source of supply code	731,680	777,498	1,201,648	2,710,826
Of the above, the number of competitively procured parts with technical data[a]	103,152	117,090	250,335	470,577
Of the above, likely mechanical/build-to-print items as determined by FSC	102,039	78,936	38,664	219,639
Of the above, active parts (last buy date >=1/1/93)	36,037	23,924	15,115	74,139[b]

[a]This includes all NSNs with an Acquisition Method Code (AMC)/Acquisition Method Suffix Code (AMSC) combination equal to 1G/2G.

[b]The total is not equal to the sum of the three supply centers because some NSNs were assigned multiple sources of supply.

[6] Logistics Management Institute, *On-Demand Manufacturing: A Functional Economic Analysis*, Report DL601T1, Eric L. Gentsch, September 1997.

The Sample

After identifying 74,139 active, mechanical, competitively procured NSNs, we generated a random sample of 1,100 NSNs for which we could visually review the engineering data to determine if the parts were indeed CAD candidates. We received drawings from JEDMICS repositories for 585 NSNs.[7] Considering this response, statistics on the basis of this sample are precise to within plus or minus four percentage points with 95 percent confidence.

No previous data indicated that any desired statistics were correlated with the supply source or other characteristics; therefore, we did not stratify the population. We did draw sample NSNs in proportion to the number of items managed by each source of supply; however, the varying response rates from the three JEDMICS repositories altered the proportional representation among the supply centers. The JEDMICS data for the 585 NSNs are divided among the supply centers (see Table 2-2). The 485 NSNs with available engineering drawings were divided among the Federal Supply Classes (see Table 2-3).

Table 2-2. Source of Supply Representation in Sample

Source of supply code	NSNs in sample
S9C	146
S9G	221
S9I	218
Total	585

Table 2-3. Federal Supply Class Representation in Sample

# of NSNs	FSC	FSC description
129	5340	Miscellaneous hardware
82	1560	Airframe structural components
39	4730	Fittings and specialties: hose, pipe, tube
37	3120	Bearings, plain, unmounted
20	5342	Miscellaneous hardware—weapon items
19	4820	Valves, non-powered
18	3020	Gears, pulleys, sprockets and transmission chains
14	2540	Vehicular furniture and accessories
14	3040	Miscellaneous power transmission equipment
13	2590	Miscellaneous vehicular components

[7] See Appendix C for a discussion of the sampling response from JEDMICS.

Table 2-3. Federal Supply Class Representation in Sample (Continued)

# of NSNs	FSC	FSC description
13	4720	Hose and tubing, flexible
9	1680	Miscellaneous aircraft accessories and components
7	1730	Aircraft ground servicing equipment
6	2840	Gas turbines, jet engines and components, aircraft
5	2910	Engine fuel system components, non-aircraft
5	4710	Pipe and tube
4	3110	Bearings, antifriction, unmounted
4	8140	Ammunition and nuclear ordnance boxes, packages and spec containers
4	9390	Miscellaneous fabricated nonmetallic materials
3	1670	Parachutes and cargo tie down equipment
3	2990	Miscellaneous engine accessories, non-aircraft
3	4930	Lubrication and fuel dispensing equipment
3	5970	Electrical insulators and insulating material
3	6650	Optical instruments, test equipment, components and accessories
3	6920	Armament training devices
2	2835	Gas turbines, jet engines and components, non-aircraft
2	3010	Torque converters and speed changers
2	4030	Fittings for rope, cable, and chain
2	4933	Weapons maintenance and repair shop specialized equipment
2	5410	Prefabricated and portable buildings
2	6695	Combination and miscellaneous instruments
1	1005	Guns, through 30 mm
1	1615	Helicopter rotor blades, drive mechanisms and components
1	2845	Rocket engines and components
1	2915	Engine fuel system components, aircraft and missile
1	4530	Fuel burning equipment units
1	4810	Valves, powered
1	5940	Lugs, terminals, and terminal strips
1	6160	Miscellaneous battery retaining fixtures and liners
1	6615	Automatic pilot mechanisms and airborne gyro components
1	6645	Time measuring instruments
1	6665	Hazard-detecting instruments and apparatus
1	8135	Packaging and packing bulk materials
1	9330	Plastics fabricated materials

SAMPLE ANALYSIS OF CAD CANDIDATES

Following sample selection, we visually reviewed the JEDMICS data available for each NSN to determine if the part was a CAD candidate. For each set of data, we analyzed and recorded numerous features.[8]

Of the 585 NSNs, 100 NSNs were defined only by military or commercial specifications and standards.[9] Of the remaining 485 NSNs, a visual review of the raster data found that our filtering process yielded 459 mechanical NSNs with available engineering data.

From our review of the engineering data, we estimated that drawings for 438 of 459 NSNs likely underwent raster-to-vector conversion during past procurements.[10] The growing use of CAD modeling software and downstream manufacturing processes that require CAD files, especially for machined, mechanical parts, greatly influenced our assessment. Also, the raster data frequently required revision or improvement. Rather than revise the drawing on paper, the manufacturers likely would have converted drawings to CAD before making the changes. In some cases, the manufacturer may have preferred the parametric modeling capabilities offered by CAD systems for parts with multiple variations.

Of the 459 NSNs, 457 had engineering data that were submitted to DLA on paper or aperture cards. Two NSNs had data that were submitted in 3-D CAD format, but were printed and scanned for JEDMICS storage, shown in Appendix E.

We estimated, therefore, that 75 percent (438 of 585 NSNs) of the sample parts have been converted to CAD in past procurements.[11] (Recall that 100 of the 585 NSNs referenced only military or commercial specifications and standards.) When applied to the 74,139 DLA-managed, active, mechanical parts identified earlier, we calculated that 55,604 NSNs likely were converted from raster to vector format during past procurements.

To help us in subsequent conversion time estimates, we made subjective legibility and complexity assessments of each mechanical part drawing using the definitions listed in Table 2-4. We provide examples of "good," "fair," and "poor" drawing legibility in Appendix E. Note that, with the exception of 67 Defense Supply Center, Richmond (DSCR) NSNs viewed in hardcopy, the images were viewed

[8] Appendix D contains an expanded description of analyzed and recorded data features.

[9] We did not review standards and specifications for CAD suitability. It is possible that they also may benefit from the conversion of drawings into CAD models.

[10] For the remaining 21 NSNs, we provided no format recommendation because of the lack of sufficient, viewable information.

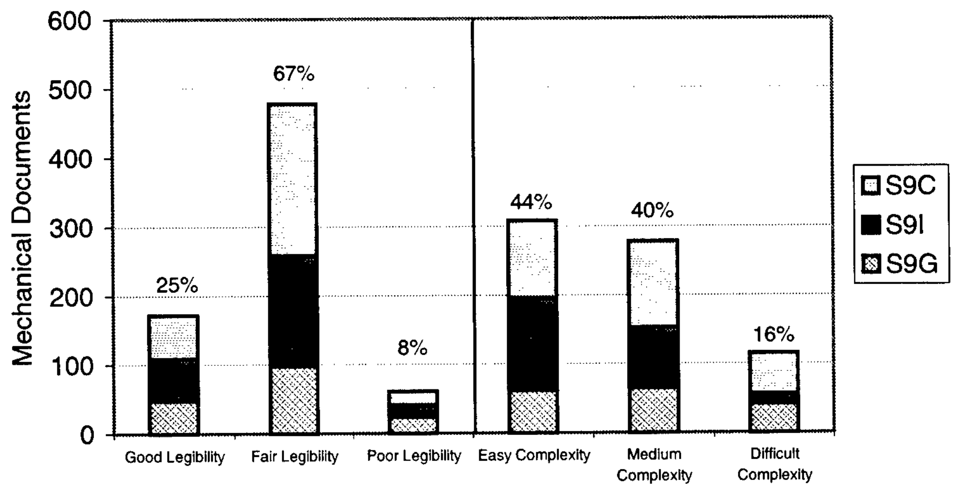
[11] The statistical sampling results in a +/-4 percent margin of error with 95 percent confidence. That is, we are 95 percent confident that the true proportion lies between 71 and 79 percent.

electronically on screen using software called ImageR.[12] Figure 2-1 summarizes our findings.

Table 2-4. Legibility and Complexity Definitions

Legibility			Complexity		
Good	Fair	Poor	Easy	Medium	Difficult
No legibility issues	Light, dark, or blurred areas may create problems for viewing the image	Image cannot be viewed, or is so difficult that assistance from the image owner is necessary	<=1 work-day to convert	2–7 work-days to convert	>=8 work-days to convert

Figure 2-1. Document Legibility and Complexity

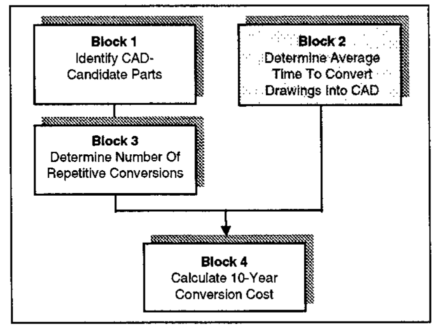


Note: The number of documents associated with each NSN varies by source of supply. In the case of DSCR, we received only top-level drawings for each NSN. In the cases of DSCP and DSCC, we received complete technical data packages, minus standards and specifications.

[12] Image resolution may improve or worsen in hardcopy. On-screen viewing allows for magnification, while hardcopy printouts of some images may improve legibility.

Chapter 3
Raster-to-Vector Conversion Time Estimation

In this chapter, we present our analysis of the hours of effort expended to convert paper or raster engineering drawings into vector files. When combined with the number of repetitive procurements and the labor cost for conversion, these data will enable us to estimate DLA's total conversion cost.



Data Identification and Collection

In our investigation, we sought organizations that have recorded the time required to convert paper or raster drawings to proprietary and neutral CAD models. We identified several organizations that have measured the percentage of correctness incurred in CAD-to-CAD and CAD-to-STEP translations, but we uncovered few organizations tracking conversion times or costs.

The South Carolina Research Authority (SCRA) located in North Charleston, SC, has conducted several projects where "seat time"[1] was recorded for each phase of the conversion process. SCRA data included conversion of raster files to STEP AP203 and AP224 formats, as well as to the IGES format, for more than 300 parts.

We collected conversion data for an additional 42 parts from Science Applications International Corporation (SAIC). In a pilot effort for the Defense Supply Center, Columbus (DSCC) to provide DoD bidders with a complete set of documentation, SAIC converted part drawings contained in technical data packages (TDPs) from raster to proprietary and neutral formats.

We also estimated the conversion time for 259 parts from our random sample. Unlike the sources above, which represent actual conversions, our figures represent a conversion estimate.

[1] "Seat time" is the time spent by a CAD technician to convert an assembled, validated paper or raster drawing package to proprietary and neutral CAD formats. Seat time does not include work stoppages between conversion activities to correct, update, and validate data.

SCRA Conversion Data

SCRA compiled its data from manufacturing projects conducted for DoD under the auspices of the Rapid Acquisition of Manufactured Parts (RAMP) Program. The objective of these projects was to demonstrate the usefulness of STEP in product data generation, manufacturing process planning, procurement, and fabrication.

For the projects, SCRA and the government selected machined parts with low to medium complexity. SCRA generated CAD and STEP files using its RAMP Product Data Translation System for Mechanical Parts (RPTS MP). RPTS MP is a Pro/E-based system.

Table 3-1 lists the projects conducted by SCRA, the time frame in which they occurred, and the number of parts converted during each project.[2]

Table 3-1. SCRA Projects

Project	Time frame	Number of parts
Phase 1	5 August 1994 – 17 December 1995	20
Phase 2	25 August 1994 – 5 December 1996	64
Phase 3	11 September 1996 – 19 August 1998	60
Texas Instruments (TI)	19 March 1996 – 16 October 1996	59
Small/Medium Manufacturers (SMM)	27 August 1996 – 15 July 1997	40
Focus: HOPE	5 September 1996 – 6 January 1997	21
Anniston Army Depot	26 February 1997 – 12 June 1998	11
Rock Island Arsenal	8 February 1998 – 14 July 1998	29
Yokosuka Naval Base	18 February 1998 – 16 June 1998	10
Total parts		314

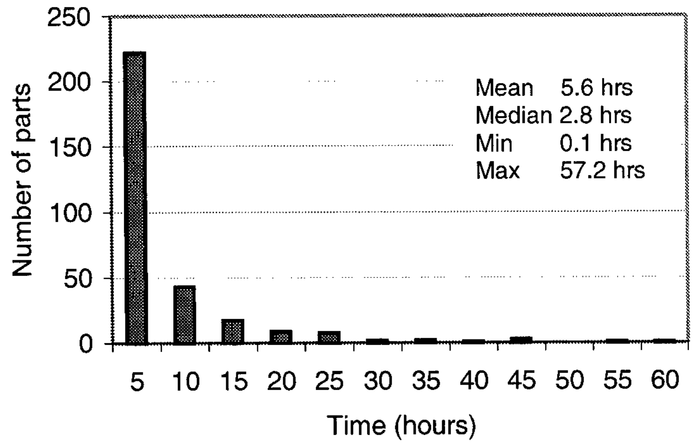
The conversion time data collected by SCRA covered the range of activities required to convert a paper or raster drawing to STEP formats AP203 and AP224 and IGES, including the creation and validation of a 3-D CAD model. Figure 3-1 shows the distribution of total recorded seat time for the 309[3] parts that underwent conversion to STEP and IGES files.[4]

[2] SCRA has compiled detailed reports on several of the projects. These reports are referenced in Appendix H.

[3] We excluded five parts with outlying data points. Appendix F contains details.

[4] Phase 1 project parts (20 parts) were not converted to IGES files.

Figure 3-1. SCRA STEP and IGES Conversion Time Frequency Distribution (309 Parts)



SAIC CONVERSION DATA

For DSCC, SAIC converted part drawings in TDPs from raster to proprietary and neutral 3-D CAD formats in a pilot effort to provide DoD bidders with a complete set of part documentation. Conversion time was tracked using timesheet charge codes. Unlike SCRA data, which measured "seat time" only, SAIC data reflected the time required to resolve data quality and related issues necessary to compile a complete TDP.

We collected from SAIC data for the conversion of 42 TDPs. Each TDP was converted from raster to 3-D feature-based models and 2-D detail drawings using AutoCAD 14.01 and Mechanical Desktop 3.0. Output formats, which were loaded onto a compact disc (CD), are as follows:[5]

- STEP (AP203)
- IGES (2-D detail and 3-D surface)
- ACIS (3-D solid, feature-based model)
- DWG (AutoCAD native format)
- STL (stereolithography rapid prototyping format)
- BAK (AutoCAD back-up file).

[5] The CD also contains, for DoD suppliers without a CAD system, a 3-D viewer for the ACIS file that includes zoom, pan, and rotational capabilities. A 2-D hardcopy completes the new TDP. The digital TDP packages were not submitted to a JEDMICS repository.

The pilot TDPs included assemblies and piece parts within the M1 family of U.S. Army vehicles, which is the Abrams Main Battle Tank. SAIC stratified the TDPs into three broad classes: easy, medium, and difficult. An "easy" rating included piece parts composed of 10 or fewer regular geometric shapes. A "medium" rating included single piece parts and assemblies. A "difficult" TDP was a complex piece part or an assembly composed principally of medium or complex parts. Individual parts, as well as the assembly, were modeled.

After a TDP complexity decision was made, an SAIC timesheet charge code was assigned to each category (easy, medium, or difficult). Activities charged included

- acquisition of the TDP,
- resolution of data quality issues,[6]
- conversion,
- generation of six electronic formats, and
- production of a CD-ROM containing all data plus the 3-D viewer.

Table 3-2 contains the data collected by SAIC.

Table 3-2. SAIC Conversion Data

Part complexity	Number of TDPs	Average hours/TDP
Easy	4	14
Medium	27	39
Difficult	11	70
Mean	42	45

Without knowledge of individual TDP conversion times, we assigned the average value for each part complexity to the 42 TDPs. That is, we assumed the 4 easy parts required 14 hours each; the 27 medium parts required 39 hours each; and the 11 difficult parts required 70 hours each to create a complete electronic TDP package.

LMI/TESSADA CONVERSION ESTIMATES

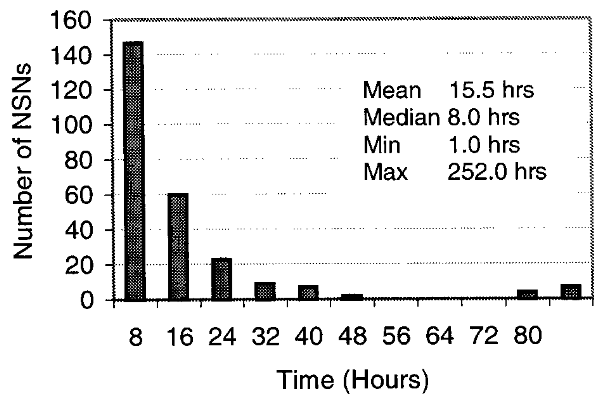
With the cooperation of Tessada & Associates, we estimated the conversion time required to create proprietary and neutral CAD models from the raster images obtained from our random sample (see Chapter 2). Our estimate included the

[6] Recall that SCRA did not record the time required to acquire the engineering data and to resolve data quality issues, such as drawing legibility, drawing accuracy, and specification changes.

creation of a Pro/ENGINEER (Pro/E) CAD model, as well as conversion to neutral STEP AP203/AP224 and IGES files. The time estimate assumed that the engineering data had been prepared for conversion (i.e., assembled, updated, and reviewed). The estimate allowed for some rework or revisions to the CAD model as part of engineering validation, but it did not include elapsed time to address more complicated image and data quality issues.

We computed the distribution of conversion times for DSCC and Defense Supply Center, Philadelphia (DSCP) parts.[7] Figure 3-2 shows the distribution of conversion time in hours for 119 DSCC NSNs and 140 DSCP NSNs.

Figure 3-2. Estimated Conversion Time Frequency Distribution (259 NSNs)



This distribution reflects a conversion time estimated on the basis of drawing size, complexity, and legibility, as determined by an experienced CAD draftsman. We undertook no conversions of the sample drawings.

Conversion Time Estimate

The SCRA and SAIC conversion time data sets, as well as our estimated conversion time data set, differed in data conversion formats, handling of data quality issues, and time measurement techniques. A comparison of the data sets is shown in Table 3-3.

[7] We obtained top-level drawings only for the DSCR parts. Conversion time estimates for DSCP and DSCC parts reflect our review of the complete engineering data package—minus standards and specifications—required to manufacture the part.

Table 3-3. Data Set Comparison

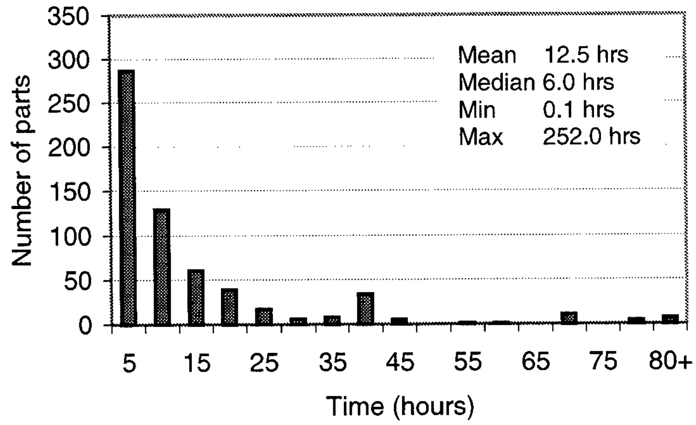
	SCRA	SAIC	LMI/Tessada
Conversion formats	Pro/E, STEP, IGES	AutoCAD, STEP, IGES, ACIS, STL	Pro/E, STEP, IGES
Data quality resolution time	Generally not included, although rework time is measured that may reflect data quality issues	Includes collection, assembly, update, and verification of legacy data	Allows for some rework time, which may reflect data quality issues
Data quality resolution elapsed time	Not included	Not included	Not included
Time measurement methodology	Actual seat times recorded in hours/ minutes/seconds	Actual TDP preparation time recorded in hours	Estimated bid time in hours (generally aligned with work weeks, e.g., 40 hrs, 80 hrs)

- *Format*: The TDPs assembled by SAIC contained a total of six electronic formats, compared to three formats each by SCRA and LMI.
- *Data quality*: "Data quality resolution time" refers to the active time required by the technician to clean, update, and validate the legacy data. In the case of SAIC, this also included the time required to locate and assemble the legacy data. "Data quality resolution elapsed time" would also include the downtime spent waiting on data resolution issues.
- *Time measurement*: Time measurement methodology refers to the technique used by each data source to record conversion times. SCRA used precise time measurements and recorded only actual time spent by the technician at a workstation. The SAIC timesheet-tracking method resulted in longer conversion times and coarser time intervals. The LMI estimated time was measured in workdays/workweeks and was grouped around the 40- and 80-hour intervals.

These measurement differences notwithstanding, the data most likely represented a conservative estimate of total conversion time. Total conversion time must take into account data quality issues and other activities (e.g., data collection, clean up, update of standards and specifications) necessary to prepare an engineering package for manufacture.

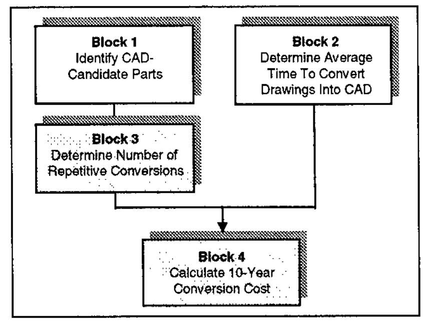
Figure 3-3 shows the distribution of conversion times for all three data sources.

Figure 3-3. SCRA, SAIC, LMI Conversion Time Frequency Distribution (610 Parts)



Chapter 4
Conversion Cost Estimation

In this chapter, we present a procurement profile of DLA CAD-candidate parts identified in Chapter 2, and calculate the DoD-incurred cost of repetitive conversions using the conversion time data described in Chapter 3.



PROCUREMENT PROFILE

Using the methodology described in Chapter 2, we estimate that at least 55,604 DLA-managed, mechanical parts are CAD-candidate parts. That is, engineering data associated with these parts likely underwent raster-to-vector conversion to facilitate manufacture during past DLA procurements. To assess the economic effect of these items without knowledge of specific NSNs, we analyzed the procurement history of the estimated 74,139 active, mechanical parts of which the CAD-candidate items were a subset.

Procurement Volume

The 74,139 NSNs represent a 10-year procurement volume of $6.68 billion, according to Haystack's procurement history database.[1] Having estimated that approximately 75 percent of these NSNs are CAD candidates, we assumed procurements were distributed evenly among CAD and non-CAD NSNs; therefore, we projected that 75 percent (or $5.01 billion) of the procurement volume was generated by CAD-candidate NSNs, shown in Table 4-1.

Table 4-1. 10-Year Procurement Volume

	NSNs	Procurement volume
Active, mechanical parts	74,139	$6.68 billion
CAD-candidate parts	55,604[a]	$5.01 billion

[a] 95 percent confidence with margin of error of +/- 2,224 NSNs.

As a check, we also queried the DLA Item & Header File for the 12-month period of April 1997 to March 1998, and determined that the 74,139 NSNs had wholesale sales of 30.9 million units valued at $432.4 million. Again, we projected that CAD-candidate NSNs generated 75 percent of the procurement

[1] We accessed the Haystack database on 6 April 1999 for the time period 1 January 1989 to 6 April 1999.

volume. The wholesale demand data are presented by source of supply code in Table 4-2.

Table 4-2. Annual Wholesale Demand for CAD-Candidate Population

Apr 1997–Mar 1998	Active, mechanical parts				CAD-candidate parts
Supply center (source of supply code)	DSCC (S9C)	DSCR (S9G)	DSCP (S9I)	Total[a]	75% of Total
NSNs	36,037	23,924	15,115	74,139	55,604
Annual demand quantity (million units)	13.2	8.5	9.6	30.9	23.2
Annual dollar demand ($ millions)	$260.2	$125.9	$50.7	$432.4	$324.3

[a]The totals are not equal to the sum of the three supply centers because some NSNs are assigned multiple sources of supply.

CAGE History

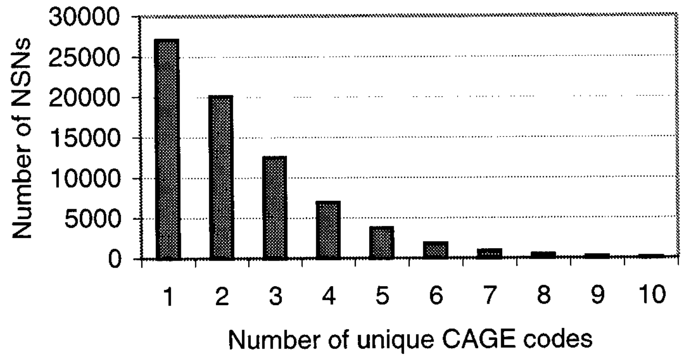
Next, using Haystack's procurement history database,[2] we determined the number of unique CAGE codes from which the 74,139 NSNs have been procured during the last 10 years. That is, for each NSN we estimated the number of times the same raster or hardcopy 2-D drawing package was sent to different manufacturers. On average, the 74,139 active, mechanical parts have been procured from 2.4 unique CAGE codes since 1 January 1990.[3] Figure 4-1 shows the frequency distribution of unique CAGE codes.

This procurement history gave us the estimated number of repetitive CAD conversions for our estimated 55,604 CAD-candidate parts. We assumed that each manufacturer created a CAD model from the raster or hardcopy drawing. Each manufacturer beyond the initial manufacturer accounted for a repetitive conversion that could have been avoided if DoD had taken delivery of the CAD model generated by the first manufacturer, then distributed the data on subsequent procurements.

[2] We accessed the Haystack's database on 6 April 1999.

[3] The average of 2.4 unique CAGE codes represents an average of 2.4 unique manufacturing companies. We have accounted for the possibility that a company may have changed name and, hence, CAGE code.

Figure 4-1. Frequency Distribution of Unique CAGE Codes (74,139 NSNs Since 1 January 1990)



Considering an average of 2.4 vendors per NSN, we estimate that for a single NSN DoD has paid

- 1.4 times more than necessary for drawings conversions to CAD, if the CAD model was acquired on the first spare parts procurement, and
- 2.4 times more than necessary, if the CAD model was acquired from the weapon system's original manufacturer at the time of system acquisition.

CAD Conversion Costs

We used the procurement and conversion data to estimate the CAD conversion cost DLA incurred.

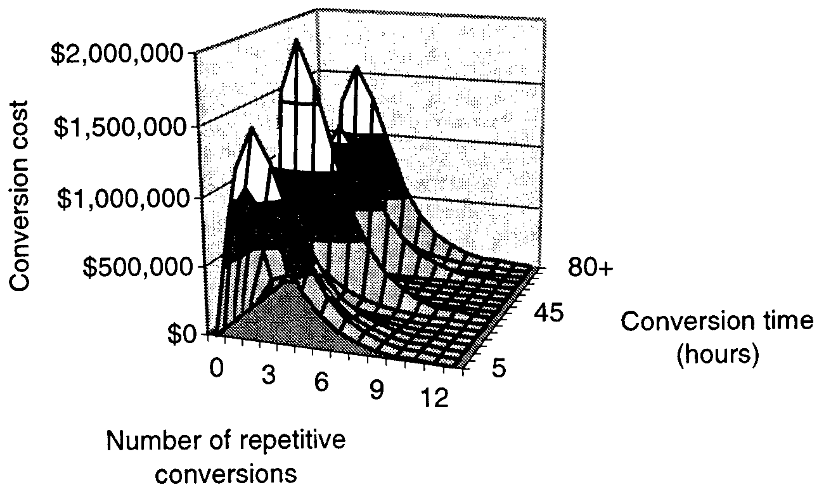
We assumed independence between the number of unique CAGE codes and CAD conversion time. In some cases it may be true that complex parts are procured from a smaller vendor base; likewise, simple parts may be obtained from a broad supplier base. For our analysis, we assumed no linkage between the number of manufacturers and conversion time.

For CAD model creation and validation, we assumed a labor rate of $50 per hour.

Figure 4-2 shows the resulting joint distribution of conversion costs as a function of conversion time and the number of repetitive conversions beyond the first spare parts procurement.[4] The costs are stratified around the 40- and 80-hour time periods primarily because of the conversion time measurement methodology. LMI provided conversion time estimates for 259 of the 610 parts in terms of workdays/workweeks, rather than hours/minutes.

[4] Appendix G contains the details of our conversion cost calculations using the joint probability distribution of two independent variables.

Figure 4-2. Joint Distribution of Mean Conversion Cost (55,604 CAD-Candidate Parts Since 1 January 1990)



The result is a conversion cost to DLA of $48 million for 55,604 parts since 1 January 1990. DLA annually spent approximately $4.8 million for repetitive raster-to-vector conversions of mechanical parts. This annual cost is equivalent to 1.5 percent of the annual dollar demand for these items in the 12 months before June 1998.

As a check, we also used a simpler approach. We calculated a similar avoidable 10-year cost of $49 million using Equation 4-1.[5]

$$\begin{aligned} Cost \ &= (55{,}604\ parts) \times (1.4\ conversions\,/\,part) \times (12.5\ hours\,/\,conversion) \\ &\times (\$50\,/\,hour) = \$48{,}653{,}500 \end{aligned} \quad \text{[Eq. 4-1]}$$

Note: We derived the average of 12.5 hours per conversion in Chapter 3.

If DoD obtained at the time of system acquisition the CAD model from the weapon system's original equipment manufacturer, DoD potentially could have avoided an additional $34.7 million in conversion costs, or a total of $83 million, shown in Equation 4-2.

$$\begin{aligned} Cost \ &= (55{,}604\ parts) \times (2.4\ conversions\,/\,part) \times (12.5\ hours\,/\,conversion) \\ &\times (\$50\,/\,hour) = \$83{,}406{,}000 \end{aligned} \quad \text{[Eq. 4-2]}$$

[5] In the joint probability distribution calculations, we omitted those few NSNs with more than 14 unique CAGE codes. This accounts for the slightly lower avoidable cost as compared with the methodology in Equation 4-1.

Chapter 5

Findings, Conclusions, and Recommendations

According to our analysis, repetitive CAD conversions following the first spares procurement have cost an extra $48 million during the last 10 years. If DoD had obtained CAD data from the original equipment manufacturer, an additional $35 million potentially could have been avoided.

FINDINGS AND CONCLUSIONS

- Approximately 75 percent of the current raster data associated with the mechanical parts documents we examined have legibility problems. Nearly 8 percent of the documents were certain to require some assistance from the image owner, resulting in production delays. Updates to specifications and standards often were required, and revisions to raster data were not possible (except pixel-by-pixel). Revised CAD data can be printed and scanned, but these data fail to relate data inherent in the CAD file itself.

- During the last 10 years, DLA's suppliers converted the engineering data for an estimated 55,604 mechanical parts from raster to vector format.

- Conversions cost an average of $8.3 million per year that could have been avoided if DoD had procured vector data with the original weapon system. This amounted to approximately 2.6 percent of the annual procurement volume for those parts.

- Considering that DLA actually received raster data from the military services, the average annual conversion cost that it could have avoided was $4.8 million. This assumes that DLA could have procured CAD data from the first spares manufacturer and then redistributed the data.

- There is a potential for large cost savings, but issues such as the cost of storing, maintaining, and distributing vector data must be investigated first.

- Additional benefits to lead-time and quality remain to be quantified. Our analysis suggests that data maintained by DLA can be significantly improved through representation in CAD models, possibly leading to significant operational benefits.

RECOMMENDATIONS

On the basis of our findings, LMI recommends that DLA should take the following actions:

- Establish or procure as services the systems and procedures to validate, store, maintain, and distribute CAD data.
- Take delivery of CAD data for parts modeled at government expense. In addition, DoD weapons acquisition programs should obtain access to CAD data for part designs funded by the government and likely to be competitively procured as spares.
- Avoid wholesale conversion of legacy data. Instead, take delivery of CAD data as available in future procurements when the savings from future procurements are expected to exceed the cost of conversion, storage, and maintenance.
- Avoid incremental funding to suppliers for DLA-requested CAD data, because the cost of CAD conversion is built into the production price.

Appendix A
CAD-Candidate Filtering Process

In this appendix, we expand on our Chapter 2 discussion of estimating the number of DLA-managed parts that have been converted from raster to vector format in past procurements.

Using the DLA Item & Header File and the Federal Logistics Information System (FLIS) accessed through the Haystack online database service, we extracted those DLA-managed parts likely in the manufacturing process to need conversion of raster data. Specifically, we executed the following steps to identify CAD-candidate parts:

- We extracted a list of NSNs from Haystack/FLIS that corresponded to a source of supply (SOS) code equal to S9C (DSCC), S9G (DSCR), and S9I (DSCP). The management of DLA's hardware items falls under these three supply centers. DSCC carries two SOS codes: one (S9C) for the former Defense Construction Supply Center, and one (S9E) for the former Defense Electronics Supply Center. We included only items coded S9C, which were more likely to be mechanical parts.

- We excluded all NSNs except those with an Acquisition Method Code (AMC)/Acquisition Method Suffix Code (AMSC) combination equal to 1G/2G. We selected those parts with an AMC code equal to "1" or "2," signifying that DLA procures that item competitively. An AMSC of "G" indicates that the government maintains technical data for that item.

- We excluded all Federal Supply Classes (FSCs) unlikely to contain mechanical, non-commercial parts. For example, we excluded FSCs 6110 (Electrical Control Equipment) and 6125 (Rotating Electrical Converters) because electrical parts are more appropriately addressed by other STEP Application Protocols. We excluded FSCs 3415 (Grinding Machines) and 3431 (Electric Arc Welding Equipment) because of their commercial nature. We excluded FSCs 2945 (Engine Air and Oil Filters/Cleaners) and 4010 (Chain and Wire Rope) because of their non-mechanical, non-machined nature. If we doubted the nature of the FSC, we included it rather than excluded it.

- We excluded all NSNs, on the basis of DLA Item & Header File data, with a Last Buy Date (LBD) before 1 January 1993. For those NSNs with no Item & Header File LBD data, we used Haystack/FLIS data to determine if the part had an LBD on or after 1 January 1993.

Appendix B
Federal Supply Classes

One of our first steps in identifying DLA-managed parts likely to have undergone manufacturer conversion from drawings to CAD models in previous procurements was to examine the FSCs managed by the three hardware supply centers and eliminate those classes unlikely to contain mechanical, non-commercial parts.

Tables B-1 through B-3 contain lists of FSCs managed by each supply center. If the FSC is followed by "Yes," we included all NSNs in that FSC in our analysis. If the FSC is followed by "No," we excluded all NSNs in that FSC from our analysis. Where doubt existed, FSCs were included rather than excluded.

Table B-1. Defense Supply Center, Columbus FSCs

FSC	FSC description	Include?
1005	Guns, through 30 mm	Yes
1010	Guns, over 30 mm up to 75 mm	Yes
1015	Guns, 75 mm through 125 mm	Yes
1020	Guns, over 125 mm through 150 mm	Yes
1025	Guns, over 150 mm through 200 mm	Yes
1030	Guns, over 200 mm through 300 mm	Yes
1035	Guns, over 300 mm	Yes
1040	Chemical Weapons and Equipment	Yes
1045	Launchers, Torpedo and Depth Charge	Yes
1055	Launchers, Rocket and Pyrotechnic	Yes
1075	Degaussing and Mine Sweeping Equipment	Yes
1080	Camouflage and Deception Equipment	No
1090	Assemblies Interchangeable Between Weapons In 2 or More Classes	Yes
1095	Miscellaneous Weapons	Yes
1450	Guided Missile Handling and Servicing Equipment	Yes
1610	Aircraft Propellers and Components	Yes
1615	Helicopter Rotor Blades, Drive Mechanisms and Components	Yes
1620	Aircraft Landing Gear Components	Yes
1630	Aircraft Wheel and Brake Systems	Yes
1650	Aircraft Hydraulic, Vacuum and De-icing System Components	Yes
1710	Aircraft Landing Equipment	Yes
1720	Aircraft Launching Equipment	Yes

Table B-1. Defense Supply Center, Columbus FSCs (Continued)

FSC	FSC description	Include?
1730	Aircraft Ground Servicing Equipment	Yes
1740	Airfield Specialized Trucks and Trailers	Yes
2010	Ship and Boat Propulsion Components	Yes
2020	Rigging and Rigging Gear	Yes
2030	Deck Machinery	Yes
2040	Marine Hardware and Hull Items	Yes
2050	Buoys	Yes
2090	Miscellaneous Ship and Marine Equipment	Yes
2510	Vehicular Cab, Body, Frame Structural Components	Yes
2520	Vehicular Power Transmission Components	Yes
2530	Vehicular Brake, Steering, Axle Wheel Components	Yes
2540	Vehicular Furniture and Accessories	Yes
2590	Miscellaneous Vehicular Components	Yes
2620	Tires and Tubes, Pneumatic, Aircraft	No
2805	Gas Reciprocating Engines and Components, Excluding Aircraft	Yes
2815	Diesel Engines and Components	Yes
2825	Steam Turbines and Components	Yes
2895	Miscellaneous Engines and Components	Yes
2910	Engine Fuel Systems Components, Non-aircraft	Yes
2920	Engine Electrical Systems Components, Non-aircraft	No
2930	Engine Cooling Systems Components, Non-aircraft	Yes
2940	Engine Air and Oil Filters, Strainers, and Cleaners, Non-aircraft	No
2990	Miscellaneous Engine Accessories, Non-aircraft	Yes
3010	Torque Converters and Speed Changers	Yes
3020	Gears, Pulleys, Sprockets and Transmission Chains	Yes
3030	Belting, Drive Belts, Fan Belts and Accessories	No
3040	Miscellaneous Power Transmission Equipment	Yes
3740	Pest, Disease, and Frost Control Equipment	No
3770	Saddlery, Harness, Whips and Furnishings	No
3805	Earth Moving and Excavating Equipment	No
3810	Cranes and Crane-shovels	No
3815	Crane and Crane-shovel Attachments	No
3820	Mining, Rock Drilling, Earth Boring Equipment, Related	No
3825	Road Clearing, Cleaning, and Marking Equipment	No
3830	Truck and Tractor Attachments	Yes
3835	Petroleum Production and Distribution Equipment	No
3895	Miscellaneous Construction Equipment	No

Table B-1. Defense Supply Center, Columbus FSCs (Continued)

FSC	FSC description	Include?
3910	Conveyors	No
3930	Warehouse Trucks and Tractors, Self-propelled	No
3950	Winches, Hoists, Cranes, and Derricks	No
3960	Elevators and Escalators	No
4210	Fire Fighting Equipment	No
4220	Marine Lifesaving and Diving Equipment	Yes
4310	Compressors and Vacuum Pumps	Yes
4320	Power and Hand Pumps	Yes
4330	Centrifugal, Separators, and Pressure and Vacuum Filters	Yes
4410	Industrial Boilers	Yes
4420	Heat Exchangers and Steam Condensers	Yes
4430	Industrial Furnaces, Kilns, Lehrs, and Ovens	Yes
4440	Dryers, Dehydrators, and Anhydrators	Yes
4460	Air Purification Equipment	Yes
4510	Plumbing Fixtures and Accessories	No
4520	Space Heating Equipment and Domestic Water Heaters	No
4530	Fuel Burning Equipment Units	Yes
4540	Miscellaneous Plumbing, Heating, and Sanitation Equipment	Yes
4610	Water Purification Equipment	Yes
4620	Water Distillation Equipment, Marine and Industrial	Yes
4710	Pipe and Tube	Yes
4720	Hose and Tubing, Flexible	Yes
4730	Fittings and Specialties; Hose, Pipe, Tube	Yes
4810	Valves, Powered	Yes
4820	Valves, Non-powered	Yes
4910	Motor Vehicle Maintenance and Repair Shop Specialized Equipment	Yes
4920	Aircraft Maintenance and Repair Shop Specialized Equipment	Yes
4921	Torpedo Maintenance, Repair, and Checkout Specialized Equipment	Yes
4923	Depth Charges and Underwater Mines Maintenance, Repair and Checkout	Yes
4930	Lubrication and Fuel Dispensing Equipment	Yes
4940	Miscellaneous Maintenance and Repair Shop Specialized Equipment	Yes
5305	Screws	No
5306	Bolts	No
5307	Studs	No

Table B-1. Defense Supply Center, Columbus FSCs (Continued)

FSC	FSC description	Include?
5310	Nuts and Washers	No
5330	Packing and Gasket Materials	No
5340	Miscellaneous Hardware	Yes
5342	Miscellaneous Hardware – Weapon Items	Yes
5355	Knobs and Pointers	No
5360	Coil, Flat, and Wire Springs	No
5365	Rings, Shims, and Spacers	No
5410	Prefabricated and Portable Buildings	Yes
5420	Bridges, Fixed and Floating	Yes
5430	Storage Tanks	No
5440	Scaffolding Equipment and Concrete Forms	No
5450	Miscellaneous Prefabricated Structures	Yes
5510	Lumber and Related Basic Wood Materials	No
5530	Plywood and Veneer	No
5640	Wallboard, Building Paper and Thermal Insulation Materials	No
5660	Fencing, Fences, and Gates	No
5670	Building Components, Prefabricated	No
5680	Miscellaneous Construction Materials	No
5970	Electrical Insulators and Insulating Material	Yes
5995	Cable, Cord, Wire Assemblies: Communication Equipment	No
6830	Gases, Compressed and Liquefied	No
8140	Ammunition and Nuclear Ordnance Boxes, Packages and Spec Containers	Yes

Table B-2. Defense Supply Center, Richmond FSCs

FSC	FSC description	Include?
1040	Chemical Weapons and Equipment	Yes
1045	Launchers, Torpedo and Depth Charge	Yes
1055	Launchers, Rocket and Pyrotechnic	Yes
1080	Camouflage and Deception Equipment	No
1090	Assemblies Interchangeable Between Weapons In 2 or More Classes	Yes
1560	Airframe Structural Components	Yes
1610	Aircraft Propellers and Components	Yes
1615	Helicopter Rotor Blades, Drive Mechanisms and Components	Yes
1670	Parachutes and Cargo Tie Down Equipment	Yes
1680	Miscellaneous Aircraft Accessories and Components	Yes
1710	Aircraft Landing Equipment	Yes
1730	Aircraft Ground Servicing Equipment	Yes
1830	Space Vehicle Remote Control Systems	No
2030	Deck Machinery	Yes
2040	Marine Hardware and Hull Items	Yes
2090	Miscellaneous Ship and Marine Equipment	Yes
2810	Gas Reciprocating Engines and Components, Aircraft and Prime Movers	Yes
2835	Gas Turbines, Jet Engines and Components, Non-aircraft	Yes
2840	Gas Turbines, Jet Engines and Components, Aircraft	Yes
2845	Rocket Engines and Components	Yes
2915	Engine Fuel Systems Components, Aircraft and Missile	Yes
2920	Engine Electrical Systems Components, Non-aircraft	No
2925	Engine Electrical Systems Components, Aircraft Prime Moving	Yes
2935	Engine System Cooling Components, Aircraft Prime Moving	Yes
2945	Engine Air and Oil Filters, Cleaners, Aircraft Prime Moving	No
2950	Turbosuperchargers and Components	Yes
2995	Miscellaneous Engine Accessories, Aircraft	Yes
3020	Gears, Pulleys, Sprockets and Transmission Chains	Yes
3040	Miscellaneous Power Transmission Equipment	Yes
3110	Bearings, Anti-friction, Unmounted	Yes
3120	Bearings, Plain, Unmounted	Yes
3130	Bearings, Mounted	No
3405	Saws and Filing Machines	No
3413	Drilling and Tapping Machines	No
3415	Grinding Machines	No
3416	Lathes	No

Table B-2. Defense Supply Center, Richmond FSCs (Continued)

FSC	FSC description	Include?
3417	Milling Machines	No
3419	Miscellaneous Machine Tools	No
3424	Metal Heat Treating and Non-thermal Equipment	No
3426	Metal Finishing Equipment	No
3431	Electric Arc Welding Equipment	No
3432	Electric Resistance Welding Equipment	No
3433	Gas Welding, Heat Cutting, and Metalizing Equipment	No
3436	Welding Positioners and Manipulators	No
3438	Miscellaneous Welding Equipment	No
3439	Miscellaneous Welding, Soldering and Brazing Supply	No
3441	Bending and Forming Machines	No
3442	Hydraulic and Pneumatic Presses, Power Driven	No
3443	Mechanical Presses, Power Driven	No
3444	Manual Presses	No
3445	Punching and Shearing Machines	No
3448	Riveting Machines	No
3449	Miscellaneous Secondary Metal Forming and Cutting Machinery	No
3450	Machine Tools, Portable	No
3455	Cutting Tools for Machine Tools	No
3456	Cutting Tools for Secondary Metal Mach	No
3460	Machine Tool Accessories	No
3465	Production Jigs, Fixtures and Templates	Yes
3510	Laundry and Dry Cleaning Equipment	No
3520	Shoe Repairing Equipment	No
3530	Industrial Sewing Machines and Mobile Textile Repair Shops	No
3610	Printing, Duplicating and Bookbinding Equipment	No
3611	Industrial Marking Machines	No
3655	Gas Generating and Dispensing Systems	Yes
3660	Industrial Size Reduction Machinery	No
3680	Foundry Machinery, Related Equipment and Supplies	No
3695	Miscellaneous Special Industry Machinery	No
3740	Pest, Disease, and Frost Control Equipment	No
3920	Material Handling Equipment, Non-self-propelled	No
3940	Blocks Tackle Rigging and Slings	No
3990	Miscellaneous Materials Handling Equipment	No
4010	Chain and Wire Rope	No
4030	Fittings for Rope, Cable, and Chain	Yes

Table B-2. Defense Supply Center, Richmond FSCs (Continued)

FSC	FSC description	Include?
4110	Refrigeration Equipment	No
4120	Air Conditioning Equipment	No
4130	Refrigeration and Air Conditioning Components	No
4140	Fans, Air Circulators, and Blower Equipment	No
4230	Decontaminating and Impregnating Equipment	No
4240	Safety and Rescue Equipment	No
4710	Pipe and Tube	Yes
4820	Valves, Non-powered	Yes
4920	Aircraft Maintenance and Repair Shop Specialized Equipment	Yes
4921	Torpedo Maintenance, Repair, and Checkout Specialized Equipment	Yes
4925	Ammunition Maintenance, Repair, and Checkout Specialized Equipment	Yes
4933	Weapons Maintenance and Repair Shop Specialized Equipment	Yes
4960	Space Vehicle Maintenance, Repair, and Checkout Specialized Equipment	Yes
5110	Hand Tools, Edged, Non-powered	No
5120	Hand Tools, Non-edged, Non-powered	No
5130	Hand Tools, Power Driven	No
5133	Drill Bits, Counterbores, and Countersinks; Hand and Machine	No
5136	Taps, Dies, and Collets: Hand and Machine	No
5140	Tool and Hardware Boxes	No
5180	Sets, Kits, and Outfits of Hand Tools	No
5210	Measuring Tools, Craftsmen's	No
5220	Inspection Gages and Precision Layout Tools	No
5280	Sets, Kits, and Outfits of Measuring Tools	No
5340	Miscellaneous Hardware	Yes
5345	Disks and Stones, Abrasive	No
5350	Abrasive Materials	No
5355	Knobs and Pointers	No
5360	Coil, Flat, and Wire Springs	No
5640	Wallboard, Building Paper, and Thermal Insulation Material	No
5826	Radio Navigation Equipment, Airborne	No
5831	Telecommunications and Public Address Systems, Airborne	No
5841	Radar Equipment, Airborne	Yes
5940	Lugs, Terminals, and Terminal Strips	Yes
5950	Coils and Transformers	No
5970	Electrical Insulators and Insulating Material	Yes

Table B-2. Defense Supply Center, Richmond FSCs (Continued)

FSC	FSC description	Include?
5975	Electrical Hardware and Supplies	No
5977	Electrical Contact Brushes and Electrodes	No
5985	Antennas, Waveguides and Related Equipment	No
5995	Cable, Cord, Wire Assemblies: Communications Equipment	No
5999	Miscellaneous Electrical and Electronic Components	No
6105	Motors, Electrical	No
6110	Electrical Control Equipment	No
6115	Generators and Generator Sets, Electrical	No
6125	Converters, Electrical, Rotating	No
6130	Converters, Electrical, Non-rotating	No
6135	Batteries, Non-rechargeable	No
6140	Batteries, Rechargeable	No
6145	Wire and Cable, Electrical	No
6150	Miscellaneous Electric Power and Distribution Equipment	No
6160	Miscellaneous Battery Retaining Fixtures and Liners	Yes
6210	Indoor and Outdoor Electric Lighting Fixtures	No
6220	Electric Vehicular Lights and Fixtures	No
6230	Electric Portable and Hand Lighting Equipment	No
6240	Electric Lamps	No
6250	Ballast, Lampholders, and Starters	No
6260	Non-electrical Lighting Fixtures	No
6320	Shipboard Alarm and Signal Systems	Yes
6340	Aircraft Alarm and Signal Systems	Yes
6350	Miscellaneous Alarm, Signal and Security Detection Systems	No
6605	Navigational Instruments	Yes
6610	Flight Instruments	Yes
6615	Automatic Pilot Mechanisms and Airborne Gyro Components	Yes
6620	Engine Instruments	Yes
6625	Electrical and Electrical Properties Measurement and Test Instruments	Yes
6635	Physical Properties Testing Equipment	Yes
6645	Time Measuring Instruments	Yes
6650	Optical Instruments, Test Equipment, Components and Accessories	Yes
6655	Geophysical Instruments	Yes
6660	Meteorological Instruments and Apparatus	Yes
6665	Hazard-Detecting Instruments and Apparatus	Yes
6670	Scales and Balances	No

Table B-2. Defense Supply Center, Richmond FSCs (Continued)

FSC	FSC description	Include?
6675	Drafting, Surveying, and Mapping Instruments	No
6680	Liquid, Gas Flow, Liquid Level and Mechanisms Motion Measuring Instruments	No
6685	Pressure, Temperature and Humidity Measurement and Control Instruments	No
6695	Combination and Miscellaneous Instruments	Yes
6720	Cameras, Still Picture	No
6730	Photographic Projection Equipment	No
6740	Photo Developing and Finishing Equipment	No
6750	Photographic Supplies	No
6760	Photographic Equipment and Accessories	No
6780	Photographic Sets, Kits, and Outfits	No
6810	Chemicals	No
6820	Dyes	No
6830	Gases, Compressed and Liquefied	No
6840	Pest Control Agents and Disinfectants	No
6850	Miscellaneous Chemical Specialties	No
6910	Training Aids	No
6920	Armament Training Devices	Yes
6930	Operational Training Devices	Yes
6940	Communication Training Devices	Yes
7105	Household Furniture	No
7110	Office Furniture	No
7125	Cabinets, Lockers, Bins, and Shelving	No
7195	Miscellaneous Furniture and Fixtures	No
7220	Floor Coverings	No
7230	Draperies, Awnings, and Shades	No
7240	Household and Commercial Utility Containers	No
7310	Food Cooking, Baking, and Serving Equipment	No
7320	Kitchen Equipment and Appliances	No
7330	Kitchen Hand Tools and Utensils	No
7360	Sets, Kits, Outfits, and Modules, Food Preparation and Serving	No
7420	Accounting and Calculating Machines	No
7510	Office Supplies	No
7520	Office Devices and Accessories	No
7530	Stationery and Record Forms	No
7610	Books and Pamphlets	No
7640	Maps, Atlases, Charts, and Globes	No

Table B-2. Defense Supply Center, Richmond FSCs (Continued)

FSC	FSC description	Include?
7690	Miscellaneous Printed Matter	No
7920	Brooms, Brushes, Mops, and Sponges	No
8020	Paint and Artists' Brushes	No
8030	Preservative and Sealing Compounds	No
8105	Bags and Sacks	No
8110	Drums and Cans	No
8115	Boxes, Cartons, and Crates	No
8120	Commercial and Industrial Gas Cylinders	No
8125	Bottles and Jars	No
8130	Reels and Spools	No
8135	Packaging and Packing Bulk Materials	Yes
8140	Ammunition and Nuclear Ordnance Boxes, Packages and Spec Containers	Yes
8145	Specialized Shipping and Storage Containers	Yes
9150	Oils and Greases: Cutting, Lubricants, and Hydraulic	No
9160	Miscellaneous Waxes, Oils, and Fats	No
9310	Paper and Paperboard	No
9320	Rubber Fabricated Materials	Yes
9330	Plastics Fabricated Materials	Yes
9340	Glass Fabricated Materials	Yes
9350	Refractories and Fire Surfacing Materials	No
9390	Miscellaneous Fabricated Nonmetallic Materials	Yes
9905	Signs, Advertising Displays, and Identification Plates	No
9920	Smokers' Articles and Matches	No
9925	Ecclesiastical Equipment, Furnishings and Supplies	No
9930	Memorials: Cemeterial and Mortuary Equipment and Supplies	No
9999	Miscellaneous Items	No

Table B-3. Defense Supply Center, Philadelphia FSCs

FSC	FSC description	Include?
1560	Airframe Structural Components	Yes
1670	Parachutes and Cargo Tie Down Equipment	No
1680	Miscellaneous Aircraft Accessories and Components	Yes
2040	Marine Hardware and Hull Items	Yes
2230	Right-of-way Construction and Maintenance Equipment, Railroad	No
2240	Locomotive and Rail Car Accessories and Components	Yes
2250	Track Material, Railroad	Yes
2420	Tractors, Wheeled	Yes
2810	Gas Reciprocating Engine and Components, Aircraft and Prime Moves	Yes
2830	Water Turbines and Water Wheels and Components	Yes
2835	Gas Turbines, Jet Engines and Components, Non-aircraft	Yes
2840	Gas Turbines, Jet Engines and Components, Aircraft	Yes
2915	Engine Fuel System Components, Aircraft and Missile	Yes
2925	Engine Electrical System Components, Aircraft Prime Moving	No
2935	Engine Systems Cooling Components, Aircraft Prime Moving	Yes
2945	Engine Air and Oil Filters, Cleaners, Aircraft Prime Moving	No
2995	Miscellaneous Engine Accessories, Aircraft	Yes
3030	Belting, Drive Belts, Fan Belts and Accessories	No
3040	Miscellaneous Power Transmission Equipment	Yes
3110	Bearings, Anti-friction, Unmounted	Yes
3120	Bearings, Plain, Unmounted	Yes
3130	Bearings, Mounted	No
3210	Sawmill and Planing Mill Machinery	No
3220	Woodworking Machines	No
3230	Tools and Attachments for Woodworking Machinery	No
3510	Laundry and Dry Cleaning Equipment	No
3520	Shoe Repairing Equipment	No
3530	Industrial Sewing Machines and Mobile Textile Repair Shops	No
3710	Soil Preparation Equipment	No
3720	Harvesting Equipment	No
3770	Saddlery, Harness, Whips and Furnishings	No
3805	Earth Moving and Excavating Equipment	No
3810	Cranes and Crane-shovels	No
3815	Crane and Crane-shovel Attachments	No
3820	Mining, Rock Drilling, Earth Boring Equipment, Related	No
3825	Road Clearing, Cleaning, and Marking Equipment	No

Table B-3. Defense Supply Center, Philadelphia FSCs (Continued)

FSC	FSC description	Include?
3830	Truck and Tractor Attachments	Yes
3835	Petroleum Production and Distribution Equipment	No
3895	Miscellaneous Construction Equipment	No
3910	Conveyors	No
3920	Mat Handling Equipment, Non-self-propelled	No
3930	Warehouse Trucks and Tractors, Self-propelled	No
3940	Blocks Tackle Rigging and Slings	No
3990	Miscellaneous Materials Handling Equipment	No
4010	Chain and Wire Rope	No
4020	Fiber Rope, Cordage, and Twine	No
4030	Fittings for Rope, Cable, and Chain	Yes
4110	Refrigeration Equipment	No
4120	Air Conditioning Equipment	No
4130	Refrigeration and Air Conditioning Components	No
4140	Fans, Air Circulators, and Blower Equipment	No
4210	Fire Fighting Equipment	No
4220	Marine Lifesaving and Diving Equipment	Yes
4230	Decontaminating and Impregnating Equipment	No
4320	Power and Hand Pumps	Yes
4430	Industrial Furnaces, Kilns, Lehrs, and Ovens	Yes
4510	Plumbing Fixtures and Accessories	No
4520	Space Heating Equipment and Domestic Water Heaters	No
4530	Fuel Burning Equipment Units	Yes
4540	Miscellaneous Plumbing, Heating, and Sanitation Equipment	Yes
4630	Sewage Treatment Equipment	Yes
4710	Pipe and Tube	Yes
4720	Hose and Tubing, Flexible	Yes
4730	Fittings and Specialties; Hose, Pipe, Tube	Yes
4820	Valves, Non-powered	Yes
4930	Lubrication and Fuel Dispensing Equipment	Yes
5305	Screws	No
5306	Bolts	No
5307	Studs	No
5310	Nuts and Washers	No
5315	Nails, Keys, and Pins	No
5320	Rivets	No
5325	Fastening Devices	No

Table B-3. Defense Supply Center, Philadelphia FSCs (Continued)

FSC	FSC description	Include?
5330	Packing and Gasket Materials	No
5331	O-Rings	No
5335	Metal Screening	No
5340	Miscellaneous Hardware	Yes
5342	Miscellaneous Hardware – Weapon Items	Yes
5355	Knobs and Pointers	No
5360	Coil, Flat, and Wire Springs	No
5365	Rings, Shims, and Spacers	No
5410	Prefabricated and Portable Buildings	Yes
5411	Rigid Wall Shelters	Yes
5430	Storage Tanks	No
5440	Scaffolding Equipment and Concrete Forms	No
5445	Prefabricated Tower Structures	Yes
5450	Miscellaneous Prefabricated Structures	Yes
5510	Lumber and Related Basic Wood Materials	No
5520	Millwork	No
5530	Plywood and Veneer	No
5640	Wallboard, Building Paper, and Thermal Insulation Material	No
5660	Fencing, Fences, and Gates	No
5670	Building Components, Prefabricated	No
5680	Miscellaneous Construction Materials	No
5805	Telephone and Telegraph Equipment	No
5815	Teletype and Facsimile Equipment	No
5830	Telecommunications and Public Address Systems, Excluding Airborne	No
5835	Sound Recording and Reproducing Equipment	No
5836	Video Recording and Reproducing Equipment	No
5995	Cable, Cord, Wire Assemblies: Communication Equipment	No
6145	Wire and Cable, Electrical	No
6210	Indoor and Outdoor Electric Lighting Fixtures	No
6220	Electric Vehicular Lights and Fixtures	No
6230	Electric Portable and Hand Lighting Equipment	No
6240	Electric Lamps	No
6250	Ballast, Lampholders, and Starters	No
6260	Non-electrical Lighting Fixtures	No
6310	Traffic and Transit Signal Systems	No
6350	Miscellaneous Alarm, Signal and Security Detection Systems	No

Table B-3. Defense Supply Center, Philadelphia FSCs (Continued)

FSC	FSC description	Include?
6675	Drafting, Surveying, and Mapping Instruments	No
6710	Cameras, Motion Picture	No
6720	Cameras, Still Picture	No
6730	Photographic Projection Equipment	No
6740	Photo Developing and Finishing Equipment	No
6750	Photographic Supplies	No
6760	Photographic Equipment and Accessories	No
6770	Film, Processed	No
6780	Photographic Sets, Kits, and Outfits	No
7310	Food Cooking, Baking, and Serving Equipment	No
7320	Kitchen Equipment and Appliances	No
7330	Kitchen Hand Tools and Utensils	No
7340	Cutlery and Flatware	No
7350	Tableware	No
7360	Sets, Kits, Outfits, and Modules, Food Preparation and Serving	No
7450	Office Type Sound Recording and Reproduction Machines	No
7670	Microfilm, Processed	No
7690	Miscellaneous Printed Matter	No
8110	Drums and Cans	No
8125	Bottles and Jars	No
8130	Reels and Spools	No
9110	Fuels, Solid	Yes
9160	Miscellaneous Waxes, Oils, and Fats	No
9340	Glass Fabricated Materials	Yes
9505	Wire, Non-electrical, Iron and Steel	No
9510	Bars and Rods, Iron and Steel	No
9515	Plate, Sheet, Strip, Foil; Iron and Steel	No
9520	Structural Shapes, Iron and Steel	No
9525	Wire, Non-electrical, Nonferrous Base Metal	No
9530	Bars and Rods, Nonferrous Base Metal	No
9535	Plate, Sheet, Strip, and Foil: Nonferrous Base Metal	No
9540	Structural Shapes, Nonferrous Base Metal	No
9545	Plate, Sheet, Strip, Foil, and Wire: Precious Metal	No
9620	Minerals, Natural and Synthetic	No
9630	Additive Metal Materials and Master Alloys	No
9640	Iron and Steel Primary and Semi-Finished Products	No
9650	Nonferrous Base Metal Refinery and Intermediate Form	No

Table B-3. Defense Supply Center, Philadelphia FSCs (Continued)

FSC	FSC description	Include?
9660	Precious Metals Primary Forms	No
9925	Ecclesiastical Equipment, Furnishings and Supplies	No
9930	Memorials: Cemeterial and Mortuary Equipment and Supplies	No

Appendix C
Statistical Sampling Response

In this appendix, we report the results of our request for JEDMICS-stored engineering data for a sample of parts.

We submitted a request to three JEDMICS sites located at DSCR, DSCP, and DSCC for the engineering data associated with a total of 1,100 NSNs. Our request yielded JEDMICS-stored engineering data for 485 NSNs. One hundred additional NSNs found in JEDMICS referenced only military or commercial specifications and standards. Engineering data for the remaining 515 NSNs were unavailable from JEDMICS for various reasons:

- NSNs may have been incorrectly coded as competitive.
- For DSCR, technical data may not have been transferred to DSCR during the Consumable Item Transfer (CIT) or Base Realignment and Closure (BRAC), and subsequently the NSN has not been required.[1]
- A military specification, military standard, federal specification, or commercial specification (e.g., National Aeronautical Standards) may have replaced a part drawing. Those NSNs, if transferred under CIT or BRAC, would not require the losing activity to send the drawings, because a standard or specification now specifies them.
- The drawings may have been awaiting quality assurance/editing reviews to ensure legibility and correct indexing.[2]
- JEDMICS sites experienced lengthy service interruptions that prevented their response to our data requests.

The results of our JEDMICS query for technical data associated with the sample of 1,100 NSNs are summarized in Figure C-1 by source of supply.

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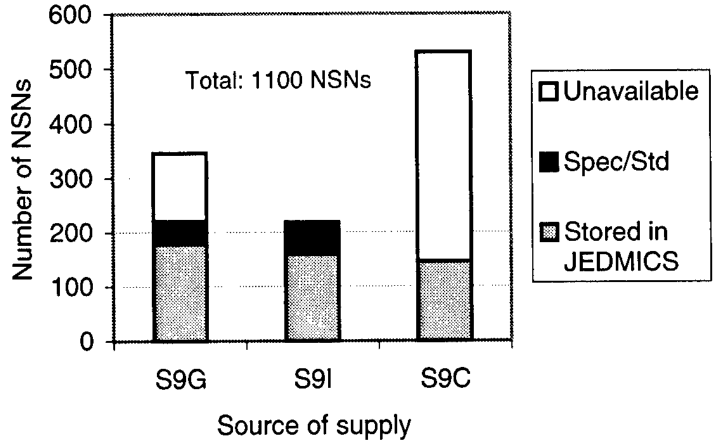
[1] If a requirement is initiated, DSCR will query the losing management activity or the original equipment manufacturer for the drawing.

[2] If, in the case of DSCR, a competitive technical data package is requested for an item awaiting quality review, both the permanent and pending storage files are checked, and the item will move immediately through the review process and be posted in the permanent storage file.

Figure C-1. JEDMICS Query Results by Source of Supply



Appendix D
Data Features

In this appendix, we describe in further detail the part features recorded for the raster data sets we obtained from JEDMICS and reviewed visually.

Table D-1 shows the following information:

- Index information for general part identification.
- CAD-appropriate feature information to help us estimate if DoD suppliers likely created a CAD model to facilitate planning and manufacturing.
  - In the "data type" field, we note whether DLA, in fact, maintains the engineering data for a particular NSN, or if DLA stores only the engineering specification.
  - In the "commodity" field, we note if the part is a machined, mechanical, noncommercial part, rather than a forged, cast, composite, or otherwise non-mechanical or commercial part.
  - "JEDMICS storage format" and "original format" indicate the drawing storage format in JEDMICS and probable original format. In some cases, a 2-D hardcopy was output from a 3-D CAD file, then scanned into C4 raster format for deposit into JEDMICS. Format information also provides insight into the format diversity of the JEDMICS repository and its use by program offices and engineering authorities. JEDMICS can handle 272 data file formats and is expandable.[1] All drawing data in our sample exist in JEDMICS in C4 raster format.
  - "Best format" indicates our evaluation of the best format for those engineering data, (i.e., we selected the format that the manufacturer likely chose to make the part. If the drawing was of a machined, mechanical part, we usually select CAD as the best format because its increasing use as modeling software and in downstream manufacturing processes requires CAD files. If the data require updates, changes, or corrections because of legibility issues or specification changes, we select CAD as the best format, because raster data cannot be changed easily.

[1] JEDMICS Program Office briefing, *JEDMICS Our Mission*, Robert Houts, 11 March 1999.

- Our records include subjective feature information such as drawing legibility and part complexity estimates because these characteristics significantly affect CAD model creation time. Data quality issues, such as illegibility, require the CAD creator to identify and contact the engineering design authority and wait for data verification. Likewise, the more complex the part, the more time required to create the CAD model. These subjective evaluations help us estimate the time required to create proprietary and neutral CAD models from 2-D raster drawings. The time estimate assumes a CAD technician with several years of experience.

Table D-1. Part Features

Index information	CAD-appropriate features	Subjective features
National Stock Number CAGE/Part Number/Revision Document Number Date Item Name Owner Source of Supply	Data Type: Drawing, Specification, Military Standard, etc. Commodity Type: Mechanical, Electrical, etc. JEDMICS Storage Format Original Format Best Format	Drawing Legibility Part Complexity CAD Model Creation Time

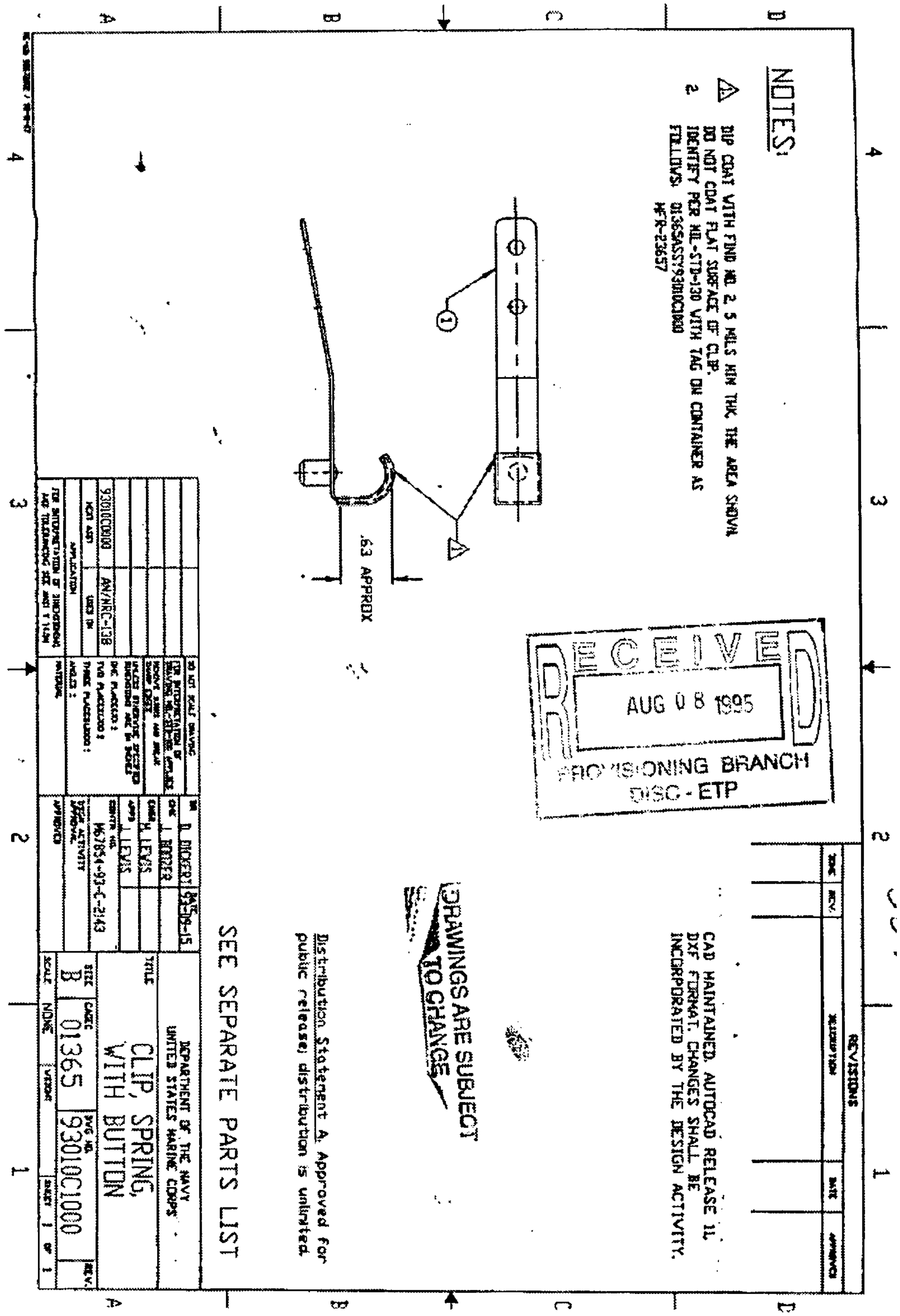
Appendix E
Sample Formats

In this appendix, we include sample images of data formats referred to in the preceding chapters.

Figure E-1 is an example of a data model submitted to the government in 3-D CAD format, but printed and scanned for storage as a C4 raster file in JEDMICS.

Figures E-2, E-3, and E-4 are examples of "good," "fair," and "poor" drawing legibility, respectively.

Figure E-1. Raster Image of CAD File Output



Note: Drawing notation states, "CAD Maintained AUTOCAD Release 11 DXF Format"

Figure E-2. Example of "Good" Drawing Legibility

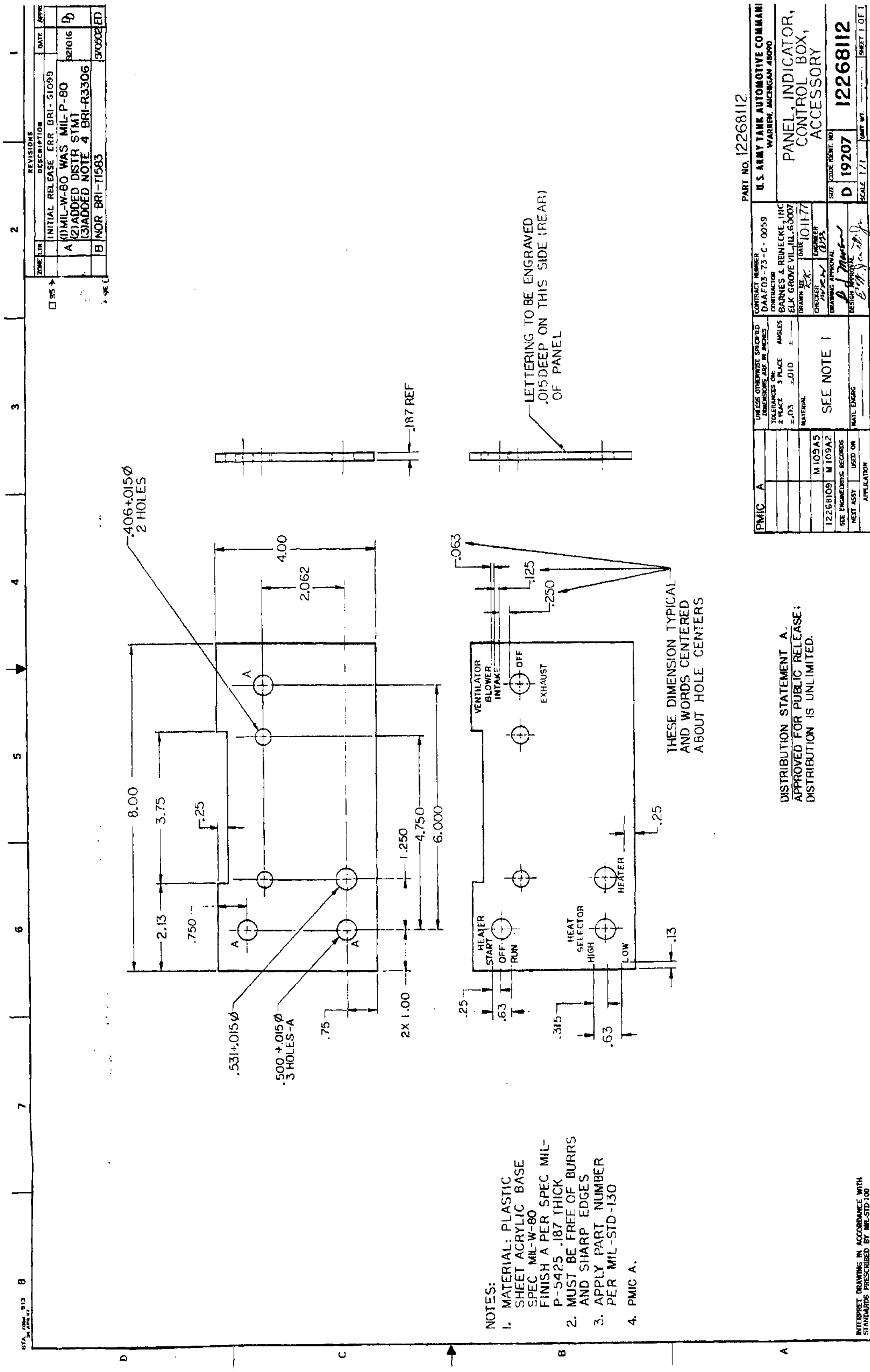


Figure E-3. Example of "Fair" Drawing Legibility

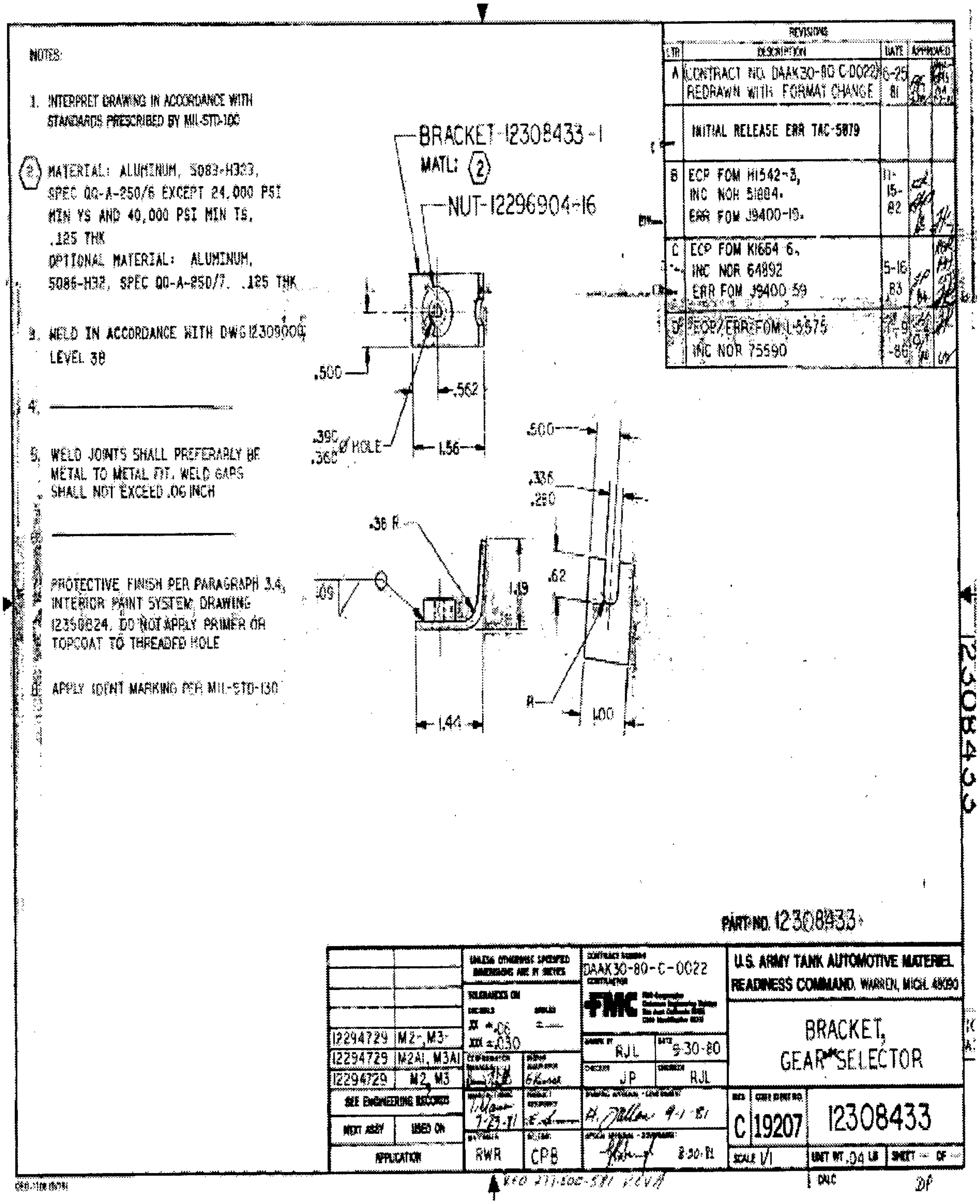
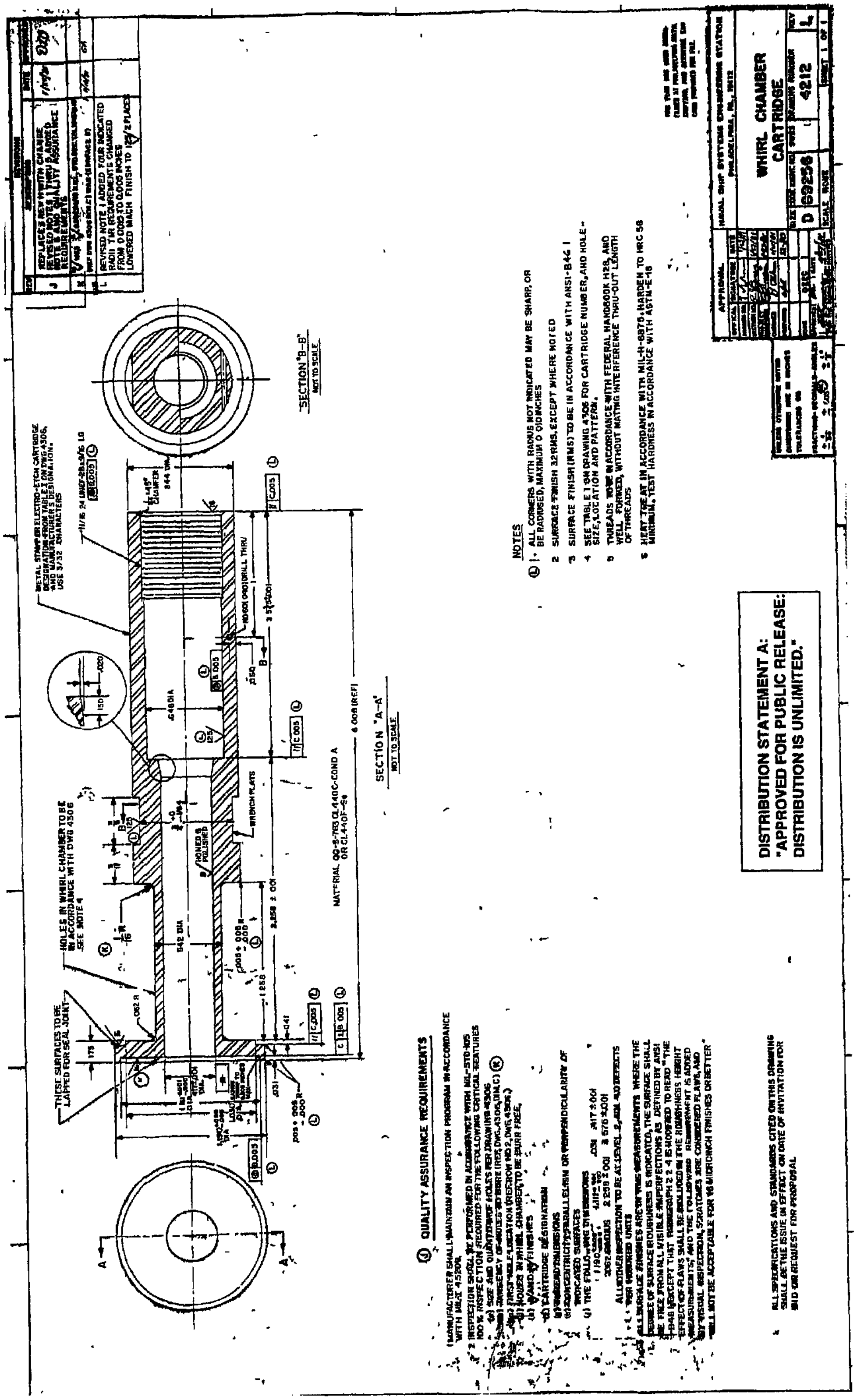


Figure E-4. Example of "Poor" Drawing Legibility



Appendix F
SCRA Conversion Data

In this appendix, we present the detailed SCRA conversion statistics.

Before we compiled the statistics, we eliminated 5 of the 314 parts from consideration. Each of the five parts possessed an outlying time for a particular conversion activity, shown in Figures F-1 through F-3. Reasons for the extreme values ranged from limited experience of the CAD technician to part complexity.

Figure F-1. IGES Drawing Creation Time Frequency Distribution (246 Parts)

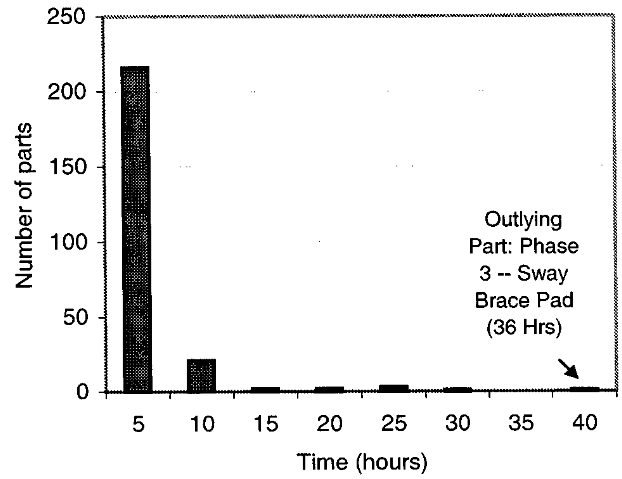


Figure F-2. Product Data Capture Time Frequency Distribution (314 Parts)

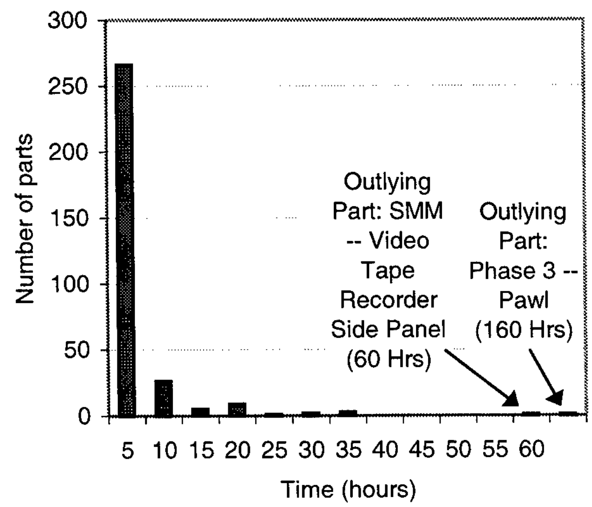
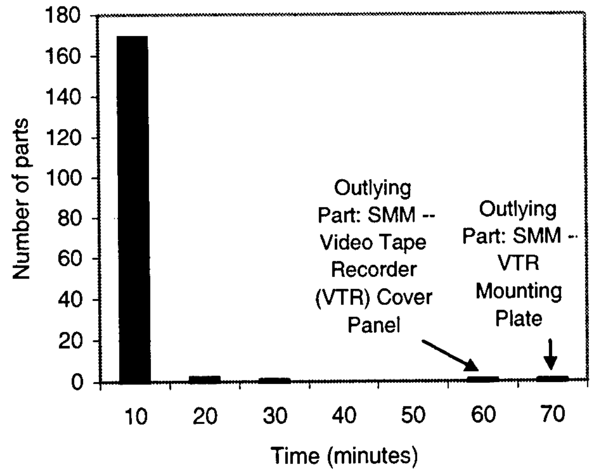


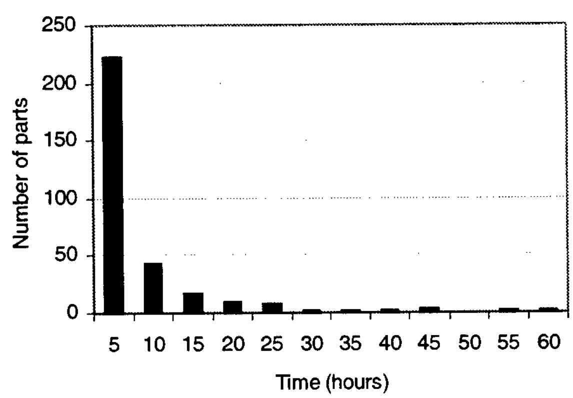
Figure F-3. STEP File Generation Time Frequency Distribution (174 Parts)



Although a total of 314 parts were handled in the nine projects, not every part had a recorded time for each activity. For example, in some of the early projects, Order Manager creation time and STEP file generation time were not recorded separately from other conversion activities. In other cases, no IGES file was created. For this reason, we constructed a frequency distribution of the total recorded conversion time for all parts, as well as frequency distributions for all parts with recorded times for a specific conversion activity.

Figure F-4 shows the distribution of total recorded seat time for the 309 parts that underwent conversion to both STEP and IGES files.[1]

Figure F-4. STEP and IGES Conversion Time Frequency Distribution (309 Parts)



Figures F-5 through F-10 present the time frequency distribution for each conversion activity. Some activities were measured in hours, some in minutes. We note how many parts had a recorded time for each activity.

[1] Only Phase 1 project parts (20 parts) were not converted to IGES files.

Figure F-5. Order Manager Time Frequency Distribution (187 Parts)

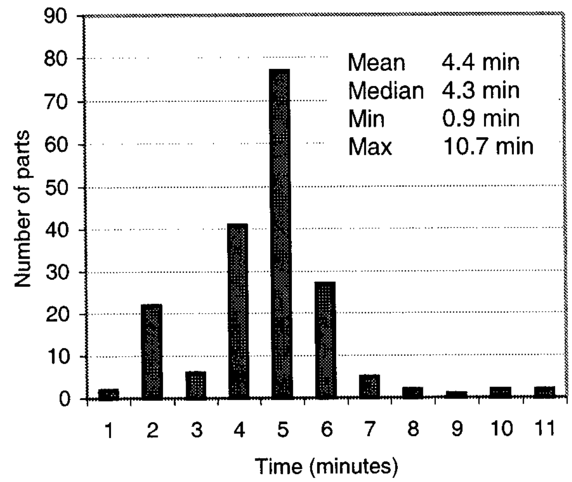


Figure F-6. Product Data Capture Time Frequency Distribution (309 Parts)

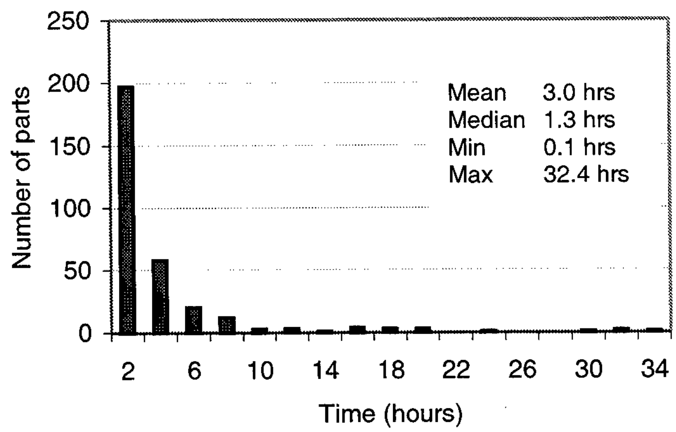


Figure F-7. Visual QA-CAD Time Frequency Distribution (60 Parts)

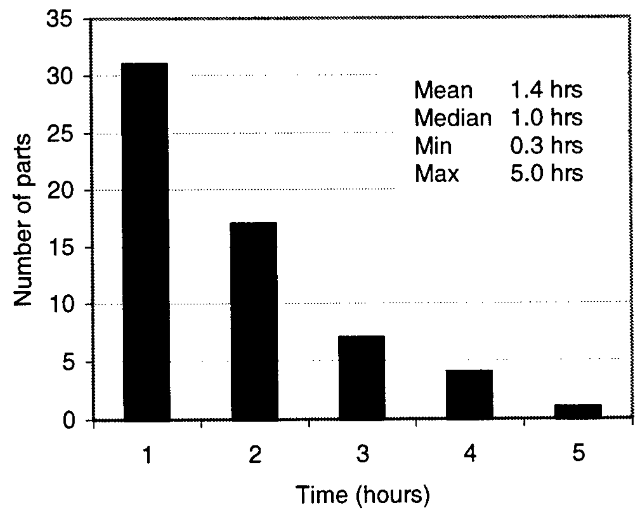


Figure F-8. STEP File Generation Time Frequency Distribution (AP203 and AP204) (171 Parts)

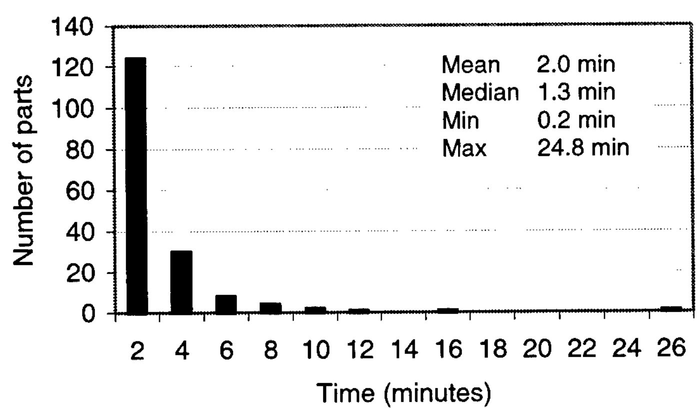


Figure F-9. IGES Drawing Creation Time Frequency Distribution (241 Parts)

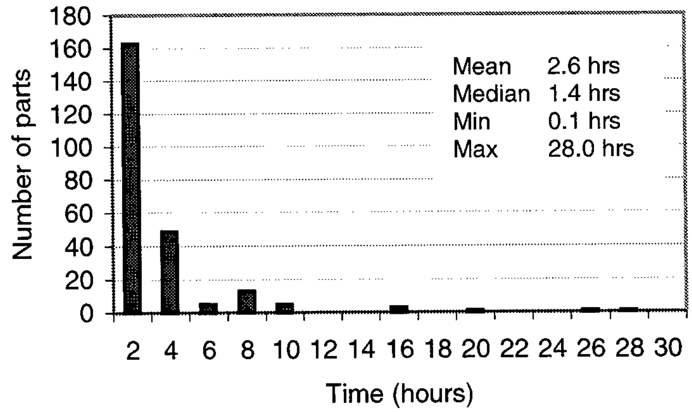


Figure F-10. Visual QA—IGES Time Frequency Distribution (65 Parts)

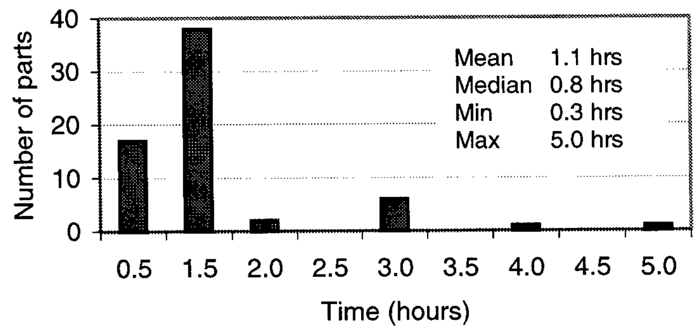
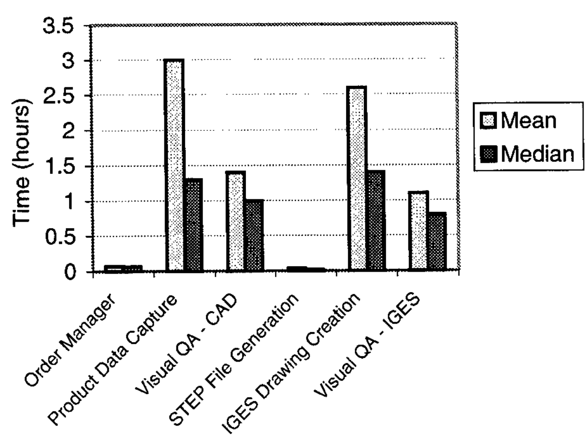


Figure F-11 shows a comparison of the mean and median time required to complete each activity.

Figure F-11. Seat Time by Activity (309 Parts)



- Creation of the 3-D CAD file (Product Data Capture) required most of the total conversion process time and varied greatly depending on operator experience, part complexity, and CAD software sophistication.

- Visual quality assurance inspection of the CAD file also required significant time in the conversion process. Although this activity was semi-automated midway through the projects, the basic activity required an individual to visually inspect the CAD model against a 2-D image, feature by feature.[2]

- Order initiation in the Order Manager and STEP file generation required a small percent of time. The RPTS-MP system generated the STEP file when the operator selected the appropriate menu option.

[2] SCRA used its new RAMP STEP Validation Process (RSVP) midway through the projects to accelerate the quality assurance function. RSVP is a Windows-based system designed to validate an AP224 file. RSVP presents the part model as a shaded or wireframe image that the user can rotate, pan, and zoom. RSVP displays each manufacturing aspect of the part with its defining data, and highlights the model's affected area. The user accepts or rejects these items according to the accuracy of the data.

Appendix G
Conversion Cost Calculations

In this appendix, we show the details of our derivation of DLA's incurred CAD conversion cost.

First, we calculate the joint distribution of two independent variables—procurement history of the 74,139 NSNs, and conversion time for 610 parts. Then we apply the joint probability distribution to the population of 55,604 CAD-candidate parts to derive the average CAD conversion cost to DLA. For all calculations, we assume a labor rate for CAD model creation and verification of $50 per hour. We select the mean time for each conversion interval (e.g., for the conversion time interval of 0 to 5 hours, we use the figure of 2.5 hours for the calculation).

Table G-1 shows the joint probability distribution of conversion cost to DLA during the last 10 years based on number of conversions and conversion time. Table G-2 shows the percentage distribution of those costs.

Table G-1. Joint Distribution of Conversion Costs (Dollars in Thousands)

		Number of Repetitive Conversions Distribution (%)									
		1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	**Total**
Conversion time (hours) **Distribution (%)**		**27.1**	**16.9**	**9.4**	**5.0**	**2.5**	**1.3**	**0.6**	**0.3**	**0.1**	**63.3**
5	**47.1**	$887[a]	$1,103	$922	$658	$408	$248	$143	$84	$42	**$4,494**
10	**21.2**	$1,196	$1,488	$1,243	$887	$550	$334	$192	$113	$56	**$6,059**
15	**10.0**	$942	$1,173	$979	$699	$434	$263	$152	$89	$44	**$4,776**
20	**6.4**	$843	$1,050	$877	$626	$388	$236	$136	$80	$40	**$4,274**
25	**2.8**	$473	$588	$491	$351	$218	$132	$76	$45	$22	**$2,396**
30	**1.0**	$204	$254	$212	$151	$94	$57	$33	$19	$10	**$1,033**
35	**1.3**	$321	$400	$334	$238	$148	$90	$52	$30	$15	**$1,528**
40	**5.6**	$1,575	$1,961	$1,638	$1,169	$725	$441	$253	$150	$74	**$7,985**
45	**0.8**	$263	$327	$273	$195	$121	$73	$42	$25	$12	**$1,331**
50	**0.0**	$0	$0	$0	$0	$0	$0	$0	$0	$0	**$0**
55	**0.2**	$65	$81	$67	$48	$30	$18	$10	$6	$3	**$329**
60	**0.2**	$71	$88	$74	$53	$33	$20	$11	$7	$3	**$360**
65	**0.0**	$0	$0	$0	$0	$0	$0	$0	$0	$0	**$0**
70	**1.8**	$917	$1,142	$954	$681	$422	$257	$148	$87	$43	**$4,650**
75	**0.0**	$0	$0	$0	$0	$0	$0	$0	$0	$0	**$0**
80	**0.7**	$383	$477	$398	$284	$176	$107	$62	$36	$18	**$1,942**
80+	**1.2**	$1,246	$1,550	$1,295	$924	$573	$348	$200	$118	$59	**$6,313**
	100	**$9,386**	**$11,680**	**$9,755**	**$6,963**	**$4,320**	**$2,624**	**$1,510**	**$891**	**$442**	**~$48M**

[a]For example, 27.1 percent of NSNs had two unique CAGE codes (i.e., one repetitive conversion), while 47.1 percent of NSNs took 0 to 5 hours to convert, or 2.5 hours on average. Therefore, the conversion cost for these items is: (55,604 NSNs)*(.271)*(.471)*(2.5 hours)*(50 dollars/hour)*(1 repetitive conversion) = $887,000 (during the last 10 years).

Table G-2. Joint Distribution of Conversion Costs in Percentages

		Number of Repetitive Conversions Distribution (%)									
		1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	**Total**
Conversion time (hours) **Distribution (%)**		**27.1**	**16.9**	**9.4**	**5.0**	**2.5**	**1.3**	**0.6**	**0.3**	**0.1**	63.3
5	**47.1**	1.84[a]	2.30	1.92	1.37	0.85	0.52	0.30	0.18	0.09	9.35
10	**21.2**	2.49	3.10	2.59	1.85	1.15	0.70	0.40	0.24	0.12	12.61
15	**10.0**	1.96	2.44	2.04	1.45	0.90	0.55	0.32	0.19	0.09	9.94
20	**6.4**	1.75	2.18	1.82	1.30	0.81	0.49	0.28	0.17	0.08	8.89
25	**2.8**	0.98	1.22	1.02	0.73	0.45	0.28	0.16	0.09	0.05	4.98
30	**1.0**	0.42	0.53	0.44	0.31	0.20	0.12	0.07	0.04	0.02	2.15
35	**1.3**	0.67	0.83	0.69	0.50	0.31	0.19	0.11	0.06	0.03	3.39
40	**5.6**	3.28	4.08	3.41	2.43	1.51	0.92	0.53	0.31	0.15	16.62
45	**0.8**	0.55	0.68	0.57	0.41	0.25	0.15	0.09	0.05	0.03	2.77
50	**0.0**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
55	**0.2**	0.13	0.17	0.14	0.10	0.06	0.04	0.02	0.01	0.01	0.68
60	**0.2**	0.15	0.18	0.15	0.11	0.07	0.04	0.02	0.01	0.01	0.75
65	**0.0**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
70	**1.8**	1.91	2.38	1.98	1.42	0.88	0.53	0.31	0.18	0.09	9.68
75	**0.0**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
80	**0.7**	0.80	0.99	0.83	0.59	0.37	0.22	0.13	0.08	0.04	4.04
80+	**1.2**	2.59	3.23	2.69	1.92	1.19	0.72	0.42	0.25	0.12	13.14
	100	**19.53**	**24.31**	**20.30**	**14.49**	**8.99**	**5.46**	**3.14**	**1.85**	**0.92**	**98.99[b]**

[a]For example, NSNs with two unique CAGE codes (i.e., one repetitive conversion that took an average 2.5 hours to convert) account for approximately 1.84 percent of the total $48 million conversion cost during the last 10 years.

[b]Total does not equal 100 percent because of rounding.

Appendix H
References

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